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(54) **Method for producing a permanent magnet and an apparatus for producing a green compact**

Verfahren zur Herstellung eines Permanentmagneten und Vorrichtung zur Herstellung eines Grünlings

Méthode de production d'un aimant permanent et appareil de formation d'un compact vert

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Description

The present invention relates to a method for producing permanent magnet and sintered compact. More particularly, the present invention relates to a method for compacting the permanent-magnet powder under magnetic field while enhancing the anisotropic property and hence enhancing magnetic properties of permanent magnets. The particles of the powder as compacted are oriented in the easy direction of magnetization. The so-oriented particles are then subjected to compacting and the particles are fixed by the compacting force. The green compact is then sintered to obtain the sintered magnet. Alternatively, resin is impregnated into the so-oriented powder so as to obtain the resin-bonded magnet. The permanent-magnet (hereinafter referred to as the "magnet") powder and resin may be compacted together to obtain the resin bonded magnet.

In addition, the present invention relates to a method for producing a sintered compact by means of die-pressing the fine powder of the ordinary material, i.e., the material other than the magnet material, under no magnetic field and then sintering the green compact. More particularly, the conventional die-pressing method is improved such that the fine powder be compacted. In the powder-metallurgy technique, not only the density of a sintered compact increases but also the grain size of a sintered compact be refined by means of lessening the particle diameter of the powder. As a result, the such sintered materials as Al and Ti are considerably strengthened, and the magnetic properties of soft magnetic ferrous material are enhanced. However, the flowability of fine powder is very poor. When the powder having poor flowability is filled in a die under gravity, the bridging phenomenon is very liable to occur in the die, and the filling density greatly varies for each filling. The weight of each green compacts (hereinafter referred to as "unit weight") varies greatly and the average filling density of the powder lowers.

The present invention is also related to a production apparatus of a green compact, which is subjected to the sintering or to the production of magnet.

Description of Related Arts

(Magnet)

Although the CIP (cold isostatic pressing) is used for compacting the magnet powder, this method is not industrially carried out, because the compacting process is complicated, that is, the magnet powder is oriented in a rubber mold under the magnetic field, then the rubber mold is immersed in a liquid medium, and the particles of the magnet powder are isostatically compacted in the liquid medium. The industrial compacting method is the die-pressing method by means of a punch(es) and die(s).

Conventional methods are the perpendicular die-pressing method, in which the magnetic field is applied to the magnet-powder in a direction perpendicular to the moving direction of the punch(es), and the axial die-pressing method, in which the magnetic field is applied parallel to the moving direction of the punch(es).

The axial die-pressing method is used for forming a flat anisotropic magnet, whose anisotropic direction is perpendicular to the major surface. The perpendicular die-pressing method is used for forming an anisotropic magnet having a relatively simple shape, whose length in the magnetically oriented direction is relatively large. Most of the magnets, particularly ferrite magnets, demanded in the market have such a shape that the magnetically oriented direction is perpendicular to the major surface.

It is generally recognized that the magnetic properties, particularly B_r and $(BH)_{max}$ of the sintered magnets industrially produced by the perpendicular die-pressing method are superior to those produced by the axial die-pressing method. However, Japanese Examined Patent Publication No. 55-26601 discloses that magnetic properties equivalent to those by the perpendicular die-pressing method can be obtained by the axial die-pressing method using a rubber mold. In this method, the magnet powder is filled in a rubber mold, which has been preliminarily set in the metal die of a die-press machine. The above-mentioned examined patent publication describes that the magnetic properties of the ferrite magnet are impaired by the disclosed die-pressing method using a rubber mold.

There is also a wet die-pressing method which is usually carried out for compacting the powder of ferrite magnet, because the magnetic powder is liable to orient in the slurry under the magnetic field, and, hence a higher orientation is obtained than by orienting the dry powder.

In the wet die-pressing, slurry with water content of from 30 to 40wt% is injected into the die cavity via an aperture in the die wall. The filter consisting of one or plurality of sheets or cloths is attached to the upper punch provided with a suction channel. During compacting by the upper and lower punches, the slurry in the die cavity is subjected to vacuum suction and the water is sucked through the filter.

(Ordinary Materials)

Since the specific surface area of the fine powder is great, it is so active that it is oxidized in air and deteriorates

in air. Particularly, the fine powder of Al-Li alloy and Ti alloy, whose reliability must be very high when they are applied for the constructional parts of an aircraft, are readily oxidized in air and, in extreme case, are spontaneously ignites. In addition, the fine powder is very sensitive to a catch-fire source. When the powder is seized between the die and punch of a die-press machine, the lubrication is lessened and the friction is increased to generate the spark which acts as the catch-fire source causing the ignition of the fine powder.

There is a limitation in the shape of a green compact which is copacted by the die-pressing method, which is one of the most frequently used shaping methods of powder. Such green compacts having unevenness or grooves, e.g., a screw, and a very elongated shape cannot be produced by the die-pressing.

It is proposed to modify the isotropic compacting in the die-pressing for example in Japanese Unexamined Patent Publication No. 49-135,805. According to this proposal, a rubber mold is set in a die, and the powder is filled in the rubber mold. The powder is therefore compacted in a moving direction of a punch(es) and also in a direction perpendicular to the former direction. The compression is therefore pseudo-isotropic. The compacting described above may hereinafter be referred to as the rubber mold die-pressing.

A rotary press-machine is known in the field of die-pressing of powder. A rotary press-machine is provided with a circular die having a plurality of die-cavities and the same number of punches as the die-cavities. A feeder box for feeding the powder into the die-cavities is slidably mounted on the circular die. During the rotation of the circular die, the die-cavities pass beneath the open bottom of the feeder box, and, the powder falls under gravity into the die-cavity. When the circular die further rotates, the bottom end of the side wall of the feeder box is displaced relative to the circular die and the die cavities, where the powder is filled, while rubbing them by such end. The punches are secured to a punch holder, whose position relative to the circular die is fixed. The punch holder therefore rotates together with the rotation of the circular die. The punches are held by the punch holder in such a manner that they can be advanced from the punch holder toward the die cavities. Driving mechanisms of the punches, such as a cam and rail, are mounted within the punch holder, and drive successively the punches when pressing the powder. Each punch is therefore pushed into each die-cavity in the sequence determined by the driving mechanisms.

Drawbacks of Prior Art and Objects of the Invention

(Magnet)

Since the powder of rare-earth cobalt magnet is filled into the rubber mold, which is preliminarily set in the die of die-press machine, according to the method of the above-mentioned Japanese Examined Patent Publication No. 55-26601, the powder is naturally filled or filled under gravity in the rubber mold. In this case, the apparent density of the powder of rare-earth cobalt magnet is approximately 18%, with the proviso that the density of the rare-earth cobalt alloy is 100%. As is known, the magnetic orientation of the powder is very sensitive to its density, and the magnetic orientation of powder filled at a higher density than the naturally filled density is difficult. It is therefore conventionally carried out to fill the magnet powder by means of a shaker or the like into a die cavity, so that the magnet powder has the naturally filled density in the die cavity.

The present inventors tested the method disclosed in Japanese Examined Publication No. 55-26601 not only with regard to the rare-earth cobalt magnet but also for the ferrite and neodymium magnets and made the following discoveries. When the naturally filled powder is compacted to produce a green compact having density of approximately 50%, the green compact cracks in the die-press machine or the rubber mold non-uniformly deforms during the die-shaping. In this case, the green compact so non-uniformly deforms that its shape cannot be adjusted by modifying the shape of the rubber mold.

The powders of the magnet are crushed considerably finer, and hence have considerably poorer flowability than those of the ordinary materials, in order to fully extract the magnetic properties thereof. Although a considerable amount of lubricant can be added to the powder of ordinary materials so as to improve the flowability, the amount of lubricant is extremely small even if it is added to the magnet powder, because the remaining carbon and the like have a detrimental effect upon the magnetic properties of the magnet powder. A small amount of the lubricant is not at all effective for improving the flowability of the magnet powder. In addition, it is possible to enhance the flowability of the ordinary materials by increasing the particle diameter. This measure is not utilized for the magnet powder, as the magnetic properties decrease. Because of the reasons as described above, the density of the naturally filled powders is as low as 18% or less for the rare-earth cobalt magnet and 16% or less for the ferrite magnet.

Japanese Examined Patent Publication No. 55-26601 mentioned above describes that the rubber mold replaces the pressure medium used in CIP. The rubber mold therefore completely surrounds the magnetic powder to isostatically apply pressure to the magnet powder. Such rubber mold therefore cannot be utilized for the wet die-pressing.

It is therefore an object of the present invention to provide a wet die-pressing method for producing a magnet, by which the orientation of a green compact is enhanced and the magnetic properties are improved by utilizing the elasticity of the rubber mold, and, further, by which a green compact is produced without causing cracks, crazing and fracture.

It is yet another object (hereinafter referred to as "the fifth object") of the present invention to provide an apparatus for producing a green compact, which is appropriate for continuous production.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 (A) through (C) illustrate incidence of cracks during compacting of a rubber mold and powder filled in the rubber mold

Figs. 2(A) through (D) illustrate a method for filling the powder in a rubber mold.

Figs. 3(A) through (D) illustrate a preliminary compacting method of powder.

Figs. 4 through 12 illustrate several embodiments of filling the powder at high density.

Figs. 13 through 15 illustrate embodiments of a rubber mold.

Fig. 16 illustrates a defect, the so-called "elephant leg" of the green compact.

Figs. 17 through 23 illustrate embodiments of a rubber mold.

Fig. 24 illustrates dimensions of a rubber mold.

Fig. 25 illustrates a dry die-press apparatus.

Figs. 26(A) through (D) illustrate several embodiments of a back-up plate.

Fig. 27 is a schematic top view of a circulating type-dry die-press apparatus according to the present invention.

Fig. 28 is a partial cross sectional view of the apparatus shown in Fig. 27.

Figs. 29(A) through (F) illustrate the movement of a cam plate used in the apparatus shown in Figs. 27 and 28.

Figs. 30(A) through (C) illustrate a method of die-pressing the magnet powder in a rubber mold under inert-gas atmosphere.

Fig. 31 is a schematic top view of another circulating type-dry die-press apparatus according to the present invention.

Fig. 32 illustrates the movement of a linear transporter used in the apparatus shown in Fig. 31.

Fig. 33 illustrates a wet-type die-press apparatus according to the present invention.

Fig. 34 is a partial view of another wet-type die-press apparatus according to the present invention.

Fig. 35 illustrates the movement or energization of the parts of the apparatus shown in Fig. 33.

Fig. 36 illustrates an embodiment of a rubber mold used in the wet die-pressing.

Fig. 37 illustrates an embodiment of the apparatus for fluidizing and filling the slurry in a rubber mold located in a reduced-pressure atmosphere.

Figs. 38(A) through (C) illustrate a pre-compacting method of slurry.

Fig. 39 is a top view of a circulating type-wet die-press apparatus according to the present invention.

Figs. 40 and 41 illustrate several embodiments of a rubber mold for producing a hollow green compact.

Fig. 42 illustrates how cracks are generated in a green compact formed by a rubber mold.

Fig. 43 illustrates the dimensions of a rubber mold.

Figs. 44(A) through (L) illustrate various combinations of materials and portions of a rubber mold.

Fig. 45 illustrates the rubber mold used in the Examples.

Fig. 46 is a schematic cross sectional view of a palette and a movable stage.

Fig. 47 is a drawing showing a rail carrying the palette.

Fig. 48 is a drawing showing a linear arrangements of the devices for producing a green compact.

Fig. 49 is a elevational view of an embodiment of the magnet production-apparatus using palettes and quadrilateral transferring passage.

Figs. 50 and 51 illustrate a means for transporting the palette.

Fig. 52 is a drawing of a guide frame.

Fig. 53 illustrates a method for weighing the powder.

Fig. 54 is a drawing of a rubber mold for forming a screw.

Figs. 55(A) and (B) illustrate the rubber molds consisting of separable parts.

Figs. 56 and 57 illustrate a method for expanding a rubber mold.

Fig. 58 illustrates laminar cracks.

Fig. 59 illustrates a method for producing a rubber mold.

Fig. 60 is a drawing of the rubber mold used in Example 18.

Fig. 61 is a drawing of the rubber mold used in Example 20.

Fig. 62 is a drawing of the rubber mold used in Example 21.

Fig. 63 is a drawing of the rubber mold used in Example 22.

Figs. 64(A), (B) and (C) are drawings of the rubber mold used in Example 23.

Figs. 65(A), (B) and (C) are drawings of the rubber mold used in Example 24.

DESCRIPTION OF THE INVENTION

Means for Preventing Cracks of a Green Compact Shaped by Using Rubber Mold

Referring to Fig. 1, a flat green compact of magnet powder shaped in a rubber mold and by a die-press machine is illustrated.

When the magnet powder is rare-earth cobalt powder, the density of the naturally filled powder in a rubber mold is from approximately 11 to 13% in most cases. The powder is then compacted so that the dimension decrease is from 30 to 40% and is hence great. During deformation of the rubber mold 10 as shown in Fig. 1(C), frictional force is generated between the portions 10s, 10k and 10u as well as between the rubber mold 10 and the metal dies (not shown). Among the deformations, the non-uniform deformation dy is generated in the cover 10u and the bottom 10k and promotes the generation of cracks 5d which extend parallel to the pressing direction of the punch. On the other hand, the non-uniform deformation dx is generated in the side portion of the rubber mold and promotes the generation of cracks 5e which extend in a direction perpendicular to the pressing direction of the punch. The non-uniform deformation dx results in a serious deformation, the so-called "elephant-leg" on the edge of a green compact.

When the magnet powder is compacted and oriented under magnetic field and is then demagnetized insufficiently, the magnetization remains in a green compact, with the result that stress is generated in the green compact due to the static magnetic energy. Therefore, even if the cracks generated in a green compact are very small, the cracks are rapidly enlarged due to the stress mentioned, thereby breaking the green compact into fragments. Particularly, when the edge of a green compact deforms to form the elephant leg, cracks due to the remaining magnetization are very likely to occur. In order to prevent the non-uniform deformation of a green compact in a rubber mold and cracks and the like, the powder must be filled in a rubber mold at a higher density than the natural density. Since the powder filled at a high density undergoes a smaller deformation than by the ordinary compacting method under magnetic field, the non-uniform deformation of the rubber mold is lessened, thereby preventing cracks and shape-failure of a green compact. The orientation is therefore high notwithstanding the high-density filling in a rubber mold, because the orientation of magnet powder is improved by the deformation of the rubber mold in a direction perpendicular to the moving direction of the punch(es), and also by preliminarily applying the magnetic field to the magnet powder prior to the compacting step.

The high density of magnet powder or mixture of magnet and resin powders filled in a rubber mold according to the present invention means that it is higher than the natural filling density by more than 1.2 times, regardless of the kind of magnet and resin materials. The naturally filled density depends mainly upon the particle diameter of the magnet and resin powder.

The density of natural filling is the apparent density of the powder filled in a rubber mold under gravity. The method for measuring apparent density stipulated in Japan Industrial Standard is a standard method for measuring the density of natural filling. However, the value obtained by this method is considerably remote from the density usually attained by the feeder box, or the measurement is impossible in extreme cases because the flowability of the magnet powder is very poor. According to the present invention, the density of natural filling is measured by filling the powder from the powder pan 90 shown in Fig. 2(A) until the top of the powder arrives at the upper frame 100 which prevents the powder 5 from overflowing from the rubber mold 10. The position of the powder pan 90 is such that the distance between the bottom end of the powder pan 90 and the bottom of the rubber mold 10 is 3.7 times the depth of the cavity of the rubber mold 10.

The filling density is 14% for the rare-earth magnets (including R-Co and R-Fe-B) having a particle diameter of from 3 to 4 μm , and 12% for the ferrite magnet having a particle diameter of approximately 0.7 μm . The high density of the rare-earth magnet and ferrite magnet is therefore 16.8% and 14.4%, respectively. The high filling density is preferably from 25% or more for the rare-earth-iron-boron magnet and rare-earth cobalt magnet. The density is more preferably 29% or more both for rare-earth magnets and ferrite magnets. When the filling density exceeds 50%, the orientation becomes impossible under the ordinary intensity of magnetic field. The filling density is preferably 50% or less.

The rubber mold used according to the present invention has a bottom and consists of rubber at least in the side portions thereof. Such rubber is hereinafter simply referred to as the rubber mold. The bottom of the rubber mold may be integrated with the other portions of the rubber mold. The lower punch or the bottom of a lower-closed die may constitute the bottom of a rubber mold. The rubber mold according to the present invention may be provided with a detachable cover consisting of metal or rubber. In this case, the cover is included in the rubber mold herein. The rubber mold may be provided with a plurality of cavities, so that a plurality of green compacts are produced at once.

According to the present invention a production method of a magnet comprises filling a slurry containing magnet powder in a rubber mold which consists of rubber at least in its side portion, in or outside a die-press machine which is provided with an upper punch, a filter and a water-suction channel formed in the upper punch; locating the filter between the upper punch and the open upper portion of the rubber mold; and compacting the rubber mold and the slurry, thereby sucking the solvent through the filter and the water-suction channel.

Prior or subsequent to filling the slurry, the inside of the rubber mold may be subjected to degassing treatment under vacuum. Advantageously the rubber mold comprises at least a top and bottom, in which at least one of the top and the bottom has a thickness t , in mm, defined by $t \leq 16h/D$, where h is thickness of the green compact, D is a positive square root of cross-sectional area of the green compact, and $D > 2h$.

The rubber mold may comprise a mandrel which is harder than other portions of the mold. The method may be carried out on a circuit which is circulated and in which the rubber mold is mounted.

The rubber used for the rubber mold is not limited but may be natural rubber, isoprene rubber, butadiene rubber, styrenebutadiene rubber, isoprene rubber, ethylene-propylene rubber, butadiene-acrylonitrile rubber, chloroprene rubber, isobutylene-isoprene rubber, ethylene-propylene rubber, ethylene-propylene rubber, chlorosulfonated polyethylene rubber, polysulfide rubber, silicone rubber, fluorinated rubber, urethane rubber, polyurethane rubber, epichlorohydrin rubber, acryl rubber, ethylene-vinyl acetate rubber, polyester rubber, epichlorohydrin rubber, chlorinated butyl rubber, chlorosulfonated polyethylene rubber, chlorinated polyethylene rubber, poly-isoprene rubber, norbornene polymer, and the like.

Plastics and wooden material, which do not completely plastically deform under the pressure of a punch, may be used. They are for example urethane, silicone resin, melamine resin, unsaturated polyester resin, epoxy resin, diallyl phthalate resin, polyimide, polyethylene, polypropylene, polystyrene, AS resin, ABS resin, polyvinyl chloride, polyvinylidene chloride, polyamide, polymethyl methacrylate, polycarbonate, polyacetal, polysulfonate, fluorine resin, cellulose acetate, and the like. Plasticizer may be added to the plastics.

In accordance with the invention, there is also provided the following production apparatus.

An apparatus for producing a green compact comprising a high-density filling device comprising a feeder for feeding the powder into the rubber molds or a loader of a preliminarily compacted powder means for enhancing the filling density of the powder; a diepress machine; and a device for removing a green compact from each rubber mold.

The apparatus may further comprise a magnetic-field generator; and/or a chamber having inert-gas atmosphere therein and locating members of the apparatus therein.

In a favoured embodiment the apparatus further comprises a circuit which is circulated, and in which the rubber molds are mounted, and along which the members of the apparatus are successively arranged. Alternatively the apparatus may further comprise a straight passage for arranging separately the members of the apparatus therealong, a rail and a reciprocating means for reciprocating a palette on which the rubber mold is detachably mounted.

Members of the apparatus may be located at either apex region or side region of a mold-supporting means having a configuration of equilateral or scalene polygon, and further palettes supporting the rubber molds may be transported in a linear movement between the adjacent locations of said members.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First and Fourth Methods

Referring to Fig. 2, the powder 5 which may be magnet powder or powder of ordinary materials, is filled at a high density by means of imparting vibration thereto. The powder 5, whose weight has been preliminarily measured, is naturally filled into the rubber mold 10 by means of flowing it down from the powder pan 90 (Fig. 2(A)). The powder 5 stacks higher than the upper surface of the rubber mold 10 up to the interior of the guide frame 100 fixed to the upper surface of the rubber mold 10. The rubber mold 10 is subsequently placed on the vibrator 41 which imparts vibration to the rubber mold during or after the powder-feeding (Fig. 2(B)). The vibrator 41 may be magnetic-type or crank-type and may generate horizontal or vertical vibration. The vibration frequency is not limited but is, for example, from 1 to 60Hz.

Pusher 121 forces down the powder 5 rising above the upper surface of the rubber mold 10, until the upper surface of the powder 5 is lowered to the same level as the upper surface of the rubber mold 10 (Fig. 2(C)). The pusher 121 and the guide frame 100 are then lifted above the rubber mold 10 (Fig. 2(D)).

Not the (uncompacted) powder but the preliminarily compacted powder may be subjected to the compacting by a die-press machine. The preliminary compacting to a high density is carried out by using a pressing device, such as a die-press machine. The attained density of a preliminarily compacted powder is preferably from 25 to 50% in the case of rare-earth magnet and from 20 to 50% in the case of ferrite magnet.

Referring to Fig. 3, a pre-compacting device comprises a die 125, a die bottom 126 consisting of a movable bottom plate, and a punch 128. The powder 5, which has been preliminarily weighed, is naturally filled into the die cavity by means of flowing it down from the powder pan 90 (Fig. 3(A)). The powder 5 is then compacted under the pressure in the range of from 15 to 100kg/cm² (Fig. 3(B)). The rubber mold 10 is then transferred beneath the pre-compacting device, the bottom 126 is pulled away from the die 125, and the punch 128 is further pushed down (Fig. 3(D)). The pre-compact 129 then falls down into the rubber mold 10. The pre-compact is preferably smaller than the inner dimension of the rubber mold 10, because the magnetic-field pulse can be effectively applied to the pre-compact 129.

The filling at high density as illustrated in Figs. 2 and 3 is carried out outside a die press-machine because the rubber mold with filled powder can be immediately compacted, as soon as it is loaded in the machine, thereby enhancing the productivity. A die (not shown in Figs. 2 and 3) may be integrally connected with the rubber mold 10. In this case the die and the rubber mold 10 with the filled powder are set together in a die-press machine.

According to the method for filling illustrated in Fig. 4, a feeder box 206 is slidably located directly on the die 2. The powder 204 falls from the feeder box 206 into the rubber mold 200 via the open top of the rubber mold 200. During the dropping of the powder 204, it is stirred by the stirrer 213. The stirrer 213 consists of rotary blades 213 secured around a shaft, and is installed within the feeder box 206, thereby eliminating the bridging of the powder 204 stacking at the open top of the feeder box 206 and hence smoothly dropping such powder into the rubber mold 200.

According to Fig. 5, the rotary blades 212 consist of blades 213 rotating around a horizontal plane. The O-ring 215 is fitted on the top part of the feeder box 206 and clearance between the shaft 215 and the feeder box 206 is gas-tightly sealed.

Figure 6 illustrates the feeding method with the same reference numerals for the parts which are the same as shown in Fig. 4. The stirrer 212 consists of the blades 216 and pusher rod 217 which is secured to the blades, so that the wide surfaces of the blades 216 can move horizontally along the longitudinal direction of the feeder box 206. The bottom edge of the blades 216 is curved to enhance the stirring efficiency. When each blade 216 passes over the die cavity of the rubber mold 200, the powder 204 is forced downwards by the vertical component of the force applied from the blade to the powder 204. The blades 216 may not consist of plates as shown in Fig. 6(B) but may consist of frames 216' as shown in Fig. 6(C) or consist of rotary blades (not shown).

In Figure 7, instead of the stirrer as shown in Fig. 4 through 6, a vibrator 218 is installed within the feeder box 204 so as to apply directly the vibration to the powder 204. The vibrator 218 may be attached to the outer surface of the feeder box 206 so as to vibrate the feeder box 206 and then indirectly the powder 204.

Referring to Fig. 8, the powder 204 is fed on the upper side of the conveyor 223 wound around the wheels 222 and is then converted to the layer along with the circulating movement of the conveyor 223. A vibrator 218 is brought into contact with the lower side of the conveyor 223 and imparts the vibration to the powder 204 being conveyed, thus enhancing its density. The powder having high density is dropped from the end of the conveyor 223.

Referring to Fig. 9, a screw rod 225, around which blades 226 are spirally secured, is mounted coaxially in the container 227. When the screw rod 225 is rotated anti-clockwise, the powder 204 is stirred in the container 227, caught between the blades 226 and fed into the direction of the outlet 227a of the container 227. Since the flowability of the magnet powder is poor and, further, the friction between the powder particles and between the powder and inner wall of the container is great, the powder moves more slowly than the rotation of the blades 226. The powder far behind each blade moves more rapidly than the powder directly behind each blade, forcing it to push into the latter powder due to the rotation of blades. The powder is pressed also due to the principle of reaction which is in opposite direction to the movement of the powder. In the embodiment shown in Fig. 9, the density of the powder is enhanced due to both the stirring and principle of reaction.

Referring to Fig. 10, the parts which are the same as those shown in Fig. 8 are denoted with the same reference numerals. The powder 204 is pressed between a pair of rolls 228 to enhance its density, and is then dropped into the rubber mold 200.

Although not shown in the drawings, the powder may be pressed in a metal die or by rolls to form a compact in the form of a sheet, which is then crushed to form granules. Such granules may be filled in a rubber mold.

The powder subjected to the processes as illustrated in Figs. 4 through 10, may be preliminarily subjected to degassing so as to enhance density.

According to Fig. 11, the powder is filled under gravity as well as magnetic field generated by the electromagnetic coils 230. The magnetic field having intensity of the preferably from 0.1 to 1T attracts the powder into the bottom of the rubber mold 200 to enhance the density.

According to Fig. 12, the electromagnets 231 are placed beneath the rubber mold 200 so as to generate the gradient magnetic field in the rubber mold 200 and hence the force F in a direction perpendicular to the gradient, attracting the powder into the bottom of the rubber mold 200. Instead of the electromagnets 231, permanent magnets generating a flux of intensity from 0.1 to 3T may be used.

The rubber mold must be a continuous body or continuously connected sections. In the latter case, the rubber mold may be a separable type as shown in Fig. 13, although the friction at the partition surfaces of the mold-sections 10a, 10b is not favorable. Furthermore, as shown in Fig. 14, portions 10c of a rubber mold 10 not in direct contact with the powder 5 may consist of granular, liquid, gel or powdery rubber, although such a structure of the rubber mold 10 is unfavorably complicated. The punches and the die of a die-press machine are denoted in Fig. 14 by reference numerals 1a, 1b and 2, respectively. Referring to Fig. 15, water, oil, or liquid rubber is filled in the die cavity 10e formed within the rubber mold 10. This would contribute to creating a compacting force as uniform as possible which is applied to the powder 5.

Referring to Fig. 17, the cylindrical side portion 10b of the rubber mold 10b is tapered (10f) at the inner, upper and

lower edges. This taper 10f is preferable for preventing the elephant legs 5a, 5b shown in Fig. 16 from occurring. The cover and bottom of the rubber mold are denoted by 12 and 10k, respectively. Instead of the taper 10f, a curved edge may be formed to prevent a crack of green compact on the edge.

In the production of the most ordinary, disc type anisotropic magnet, a rubber mold located in the die cavity is in contact with the inner peripheral wall of the die. The compacting force of a punch is converted by the rubber mold to a radial compacting force directed inwards. The rubber mold must smoothly slide on the inner peripheral wall of the die and be thoroughly compacted in order to generate strong compacting force. It is therefore preferable to apply a lubricant or anti-abrasive material between the rubber mold and die.

The lubricant, such as BN (boron nitride) may be applied on the inner wall of the rubber mold to lessen the adherence of the powder on the rubber and hence to prevent the cracks in a green compact due to the adherence. In addition, a thin rubber film may cover the inner surface of the rubber mold. This rubber film relieves inner stress of a green compact which is generated when a punch is lifted up and which may cause cracks in a green compact.

The static magnetic field is applied to the green compact of magnet powder being compacted and is in the range of from 8 to 12kOe, as in the conventional method. After the compacting step under magnetic field, demagnetization is carried out as in the conventional method.

Preferred compacting conditions are now described by using the following parameters.

Compacting ratio A_1 : compacting ratio of powder in the direction perpendicular to the moving direction of a punch(es), i.e., decrease in the cross-sectional area of green compact due to compacting/(divided by) cross-sectional area of the green compact before deformation by a punch.

Compacting ratio S_0 : compacting ratio in the moving direction of a punch(es), i.e., the dimension decrease in the moving direction of a punch(es)/(divided by) the dimension of powder before deformation by the punch(es). The dimension in this context is the average dimension.

(1) Axial Die-Pressing

Preferably $0 < A_1 \leq 6S_0$, more preferably $0.4S_0 < A_1 \leq 4S_0$, most preferably $S_0 < A_1 \leq 3.6S_0$.

When A_1 is virtually zero, the magnetic properties are not at all improved. $0 < A_1 < 0.4S_0$ is such a range that the magnetic properties are not improved outstandingly but an ultra-thin green compact or a green compact having an irregular shape can be produced. The magnetic properties are outstandingly improved at $0.4S_0 < A_1$, preferably $4S_0 < A_1$. However, at $A_1 > 6S_0$, the compacting pressure becomes impractically high.

Theoretically, the compacting condition $0 < A_1$ is always fulfilled, provided that the thickness of the rubber mold in the moving direction of a punch(es) is not zero but a finite value. However, if such thickness is very small, the rubber mold buckles and cannot shape the green compact during the pressing. The thickness of the rubber mold in the moving direction of a punch(es) should therefore be selected appropriately considering the elastic ratio of rubber so as not to incur buckling and to realize the preferable A_1 .

(2) Perpendicular Die-Pressing

$0 < A_1 \leq 4S_0$, more preferably $0 < A_1 \leq 3S_0$, most preferably $0 < A_1 \leq 2.4S_0$.

Since a clearance is formed between a rubber mold and a compact in the perpendicular die-pressing, the friction between the green compact and the rubber mold is small when the green compact is removed from the rubber mold. It is therefore possible to produce an irregular-shaped compact or an ultra-thin compact, whose production is impossible by conventional die-pressing. Similarly, as in the axial die-pressing, thickness of a rubber mold should be selected so as not to cause buckling of the rubber mold and to attain such a preferable value of A_1 as not to increase the required pressing pressure to an excessively great value.

Preferable value of A_1 for obtaining outstanding improvement of the magnetic properties is lower than that of the axial die-pressing.

The pressure applied through a punch(es) is preferably in a range of from 50 to 5000kg/cm², more preferably in a range of from 100 to 1000kg/cm². These ranges partially overlap with those of the conventional die-pressing. But their low level is lower than the conventional ranges because of entire circumference the powder is compacted due to the use of a rubber mold, which easily promotes a densifying of a green compact.

The size of magnet is not at all limited. A magnet may be from an ultra-small-sized one, such as the rotor magnet of a wrist-watch and the rotor of an electronic cylinder lock, a small-sized magnet, such as an ultra-thin magnet used in an OA (Office Automation) machine, a stepping motor-magnet, the direct-current motor of a video camera, and an actuator of a robot, to a large-sized magnet used in an MRI (magnetic resonance image).

An arc-shaped segment magnet can also be produced by the method of the present invention as is illustrated in Figs. 18 and 19, which show an elevational view and a cross-sectional view of a rubber mold. The upper and lower punches (not shown) have the same concave and convex surfaces as the upper and lower surfaces of an arc-shaped

green compact, respectively.

A prismoid can be produced by using a rubber mold 10 shown in Fig. 20. A rectangular compact having an arc-shaped top surface can be produced by using a rubber mold 10 shown in Fig. 21. A frustum of pyramid can be produced by using a rubber mold 10 shown in Fig. 22. A green compact having a flat sheet-shape with a groove through the center can be produced by using a rubber mold 10 shown in Fig. 23.

A rubber mold for producing a green compact having a complicated shape can be designed by computer simulation for shaping such a complicated shape while using the dimension data of green compacts which are produced by using rubber molds with a similar but simpler shape than the complicated shape.

The following described method, which is a simple designing method, enables to estimate the approximate shape of a rubber mold when a green compact has a simple shape and the outer shapes of the green compact and the rubber mold are the same.

The simplified designing of a rubber mold is based on the premises: the volume of a rubber mold is unchanged before and after the compression (premise 1); and the ratio of apparent density of un-compacted magnetic powder to the apparent density of a green compact is constant (premise 2).

When a rubber mold 10 consists of an annular mold 10s and is used for shaping a disc-shaped green compact 11 as is shown in Fig. 24, the following formula exists according to premise 1.

$$y\pi\{(x_0/2)^2 - (x_1/2)^2\} = Y_G\pi\{(x_0/2)^2 - (1_G/2)^2\}$$

Premise 2 is realized for the dry and ungranulated ferrite-powder to be approximately 1.9:1. The following equation is therefore obtained.

$$y\pi(x_1/2)^2 : Y_G(1_G/2)^2 = 1.9:1$$

The approximate dimension of the side portion 10s of a rubber mold can be designed based on the above two equations. The design and trial production are repeated several times, so as to modify the dimension of the side portion 10s in order to allow easy removal of a green compact from the rubber mold, and to enhance dimension accuracy of the green compact. In this modification, deformation of the rubber mold and hardness of the rubber are also taken into a consideration.

The die-press machine used in the present invention may be a hydraulic or a mechanical one. All types of die-press machines from a small-sized manual one to an automatic type can be used in the present invention. Preferred die-press machines are a twin-punch type machine, in which the upper and lower cylinders move and compact simultaneously, or a die-float type machine and a withdrawal type machine, in which only one of the upper or lower cylinders moves but the die moves synchronously to the movement of the cylinder.

The orientation of a magnet is generally defined by $Br/4\pi Is$ (Br -residual flux density, $4\pi Is$ -saturation flux density).

When the magnet powder is filled in a rubber mold at a considerably high density, particularly 29% or more, the friction force between the powder particles is greater as the filled density is higher. It is therefore difficult to provide by the static field amounting to 636800 to 955200 A/m (8 to 12kOe) used in the ordinary die-pressing under magnetic field a satisfactory rotational force for overcoming the friction of the powder particles and hence to orient the powder particles. The orientation of magnet powder tends therefore to be lowered. According to a preferred embodiment, instantaneous magnetic field is applied to the magnet powder in a rubber mold prior to the die-pressing in magnetic field. Alternatively, a stronger static field than that of the die-pressing under magnetic field is applied to the magnetic powder in a rubber mold, prior to die-pressing under magnetic field. The preliminarily applied magnetic field generates a rotational force which is sufficient for reorientation of the magnet powder. The magnet powder filled in a rubber mold is set in a die-press machine and is magnetized under pulse static field. Extremely high orientation is attained by this magnetization with a good reproducibility, notwithstanding an extremely high filling density as high as 29% or more.

Rotational force preferably imparts impact to the magnetic powder being preliminarily magnetized, so as to enhance the orientation degree thereof. The magnetic field having intensity of from 398000 to 796000 A/m (5 to 10kOe), particularly 796000 A/m (10kOe) or more, more particularly 11.94×10^6 A/m (15kOe) or more, is imparted to the magnet powder at least once, preferably twice or more. The intensity of pulse magnetic field must change greatly at the initial stage. When the specified intensity of the magnetic field is attained, it may keep a constant value or may decrease gradually.

If the magnet powder is filled in a rubber mold at very high density, there is local difference of density of the powder in the mold. If such powder is compacted without preliminary application of magnetic field, locally non-uniform deformation of a compact may occur. If a green compact has such a shape that cracks are liable to occur, the local difference in the density easily causes cracks and crazing of the green compact or deformation of a sintered compact. The de-

formed sintered compact must be machined at a great machining allowance. The above-described drawbacks resulting from the very high density can be solved by the preliminary application of the magnetic field to the magnet powder, because the agglomerated powder particles are desintegrated and uniformized thereby.

The preliminary compact can also be treated by the preliminary application of the magnetic field as described above and can advantageously attain very high density without causing cracks or the like in a green compact.

Figure 25 illustrates an apparatus for preliminary application of magnetic field and die-pressing under magnetic field. The right part of the drawing illustrates a line for filling the magnet powder in a rubber mold and loading it in a die-press machine. The electro-magnetic coil, which generates pulse and disintegrates and orients the agglomerated powder particles outside a die-press machine, is denoted by reference numeral 4a. The conveyor is denoted by 40. The vibrator 41 is in slidable contact with the conveyor 40 at its rear surface. The vibrator may be in slidable contact with the conveyor 40 at its side surface. The feeder 42 feeds magnetic powder into a rubber mold 10i provided with a bottom (hereinafter referred to as "the rubber mold 10i"). The feeding is carried out by pouring the powder 5 when the conveyor 40 stops. Simultaneously with the feeding of the powder, the rubber mold 10i is shaken by the vibrator 41 to enhance the filling density of the powder. When the conveyor 40 rotates in the direction shown by the arrow, the rubber mold 10i is moved up to the position where a cover 10h is attached, where the conveyor 40 again stops. A piston rod 53 driven by the hydraulic cylinder 52 is pushed down to tightly insert the cover 10h into the rubber mold 10. The conveyor 40 then again rotates to move the rubber mold 10i provided with the cover 10h (hereinafter referred to as "the rubber mold 10h,i") to an intermediate position between the magnetic field coils 4a, 4a, which then impart the magnetic field-pulse to the powder 5. A pusher (not shown) pushes the rubber mold 10h,i, in which the oriented magnet-powder is contained, so that it slides on the conveyor 40 and the table 44, which is located on the same level as the upper portion of a die 2, toward the die 2. The time necessary for the above-described series of movements is as follows.

(a) Pouring from the feeder 42: 0.5-30 seconds

(b) Vibration: 1-30 seconds

(c) Rotation of the conveyor (from the feeder 42 to the hydraulic cylinder 52): 1-10 seconds

(d) Inserting of a cover 10h: 1-30 seconds

(e) Rotation of the conveyor (from the hydraulic cylinder 52 to the position of the magnetic coils 4a, 4a): 1-10 seconds

(f) Imparting of the magnetic-field pulse: 1-10 seconds

(g) Rotation of the conveyor (from the position of the magnetic coils 4a, 4a to the die 2): 1-10 seconds

The control unit 50 controls the time-sequence and duration of the above-mentioned series of operations (a) through (g). More specifically, the control unit 50 generates such a command that: the conveyor 40 does not rotate during the operations (a), (b), (c) and (d); and, further, these operations are initiated when the conveyor 40 stops. In addition, operations (c), (e) and (g) must occur synchronously with each other. Since operation (f) can be the shortest and operation (b) can be the longest in the above-described case, the conveyor rotation according to (c) does not begin even if (b) is completed, until completion of (f). The control unit 50 also commands such holding and starting of the operations as described above.

The control unit 50 also commands the rotation of a motor 51 for rotating a screw rod (not shown) in the feeder. When the screw rod rotates at a specified revolution per minute, the powder is caught between the clearances of the screw and is fed into the rubber mold 10i in an amount which is specified by the total revolution of screw. The control unit 50 specifies the power, and energization-sequence and time of the power source 55 for applying the magnetic-field pulse to the powder.

Upon transmitting the end signal of the powder feeding from the motor 51, this signal is input in the control unit 50. One of the conditions for moving the conveyor is thus fulfilled. Upon inputting the end signals from operations 41, 54 and 55 to the control unit 50, all of the conditions for moving the conveyor are fulfilled. The conveyor 40 moves in the direction of the arrow for a specified distance and then stops.

The conveyor 40 may consist of a plurality of metal chains or belts arranged successively in the conveying direction. An electro-magnetic switch or a dielectric sensor is provided at each clearance between the metal chains or the like. When the electro-magnetic switch or the like detects mechanically or physically a rubber mold 10h,i, the signal is generated from the electro-magnetic switch or the like to stop the conveyor 40. The rubber molds 10h, i can be accurately stopped at a specified position.

After die-pressing, the rubber mold 10h, i is lifted up by means of the lower punch 1b and is then transferred away from the die-press machine in a direction perpendicular to the drawing.

The fine powder of ordinary materials has preferably average particle diameter of 50 μm or less, more preferably 30 μm or less, furthermore preferably 20 μm or less. The obtained sintered green compact can have a density of 95% or more based on the true density of the ordinary materials. The ordinary materials do not include magnet but may be such metals as Fe, Co, Ni, Cu, Mo, Al, Mg and Ti, and their alloys as well as compounds such as TiC and WC. The

Fe or Fe based fine powder is prepared in most cases by atomizing the material with water or inert gas, and is occasionally provided in the form of carbonyl iron. The Al or Al-based fine powder is prepared by gas-atomizing or melt-quenching. The Ti or Ti-based fine powder is prepared in most cases by repeating hydrogen adsorption and dehydrogenation. Mechanically milled fine powder may also be used. Such hard fine-powders as Fe-Co and Ti alloy-powder, whose compactibility is poor, can advantageously be compacted without adding a binder or lubricant. In addition, since the rubber mold prevents the direct contact of the fine powder with a die, the fine powder is not seized by the die. As a result, the lubricant may not be used at all. However, the binder in an amount of 1% by weight or less can be used, provided that the remaining carbon does not exert detrimental influence upon the properties of a sintered compact.

When the fine powder is filled in a rubber mold under gravity, the difference in the density of the filled powder locally varies. In addition, the green compact may crack as is described with reference to Figs. 1(A) through (C). It is therefore necessary to fill the fine powder at a high density, i.e., at least 1.15 times the natural density described with reference to Fig. 2(A). The filling density is preferably 1.3 times when the green compact has an elongated shape or great unevenness. When the fine powder is filled in a rubber mold, it should not be so seriously deformed that a desired shape of green compact is not obtained. This may occur at an extremely high-density filling, for example more than 60% of the true density.

As is shown in Fig. 52, the bottom of the guide frame 100 may have such a shape that it is virtually coincident with the top shape of the rubber mold 10. The top of the guide frame 100 may be somewhat expanded to facilitate the powder feeding.

When a conventional shaker-type feeder is used for feeding the fine powder into a rubber mold through a guide frame, the filled weight of fine powder greatly varies because of its poor flowability. It is therefore preferred to preliminarily weigh the fine powder to provide a predetermined weight and then charge the fine powder thus weighed into a rubber mold. In this embodiment, the unit weight of green compacts can be controlled very accurately. In addition, when such green compacts are sintered, the shrinkage ratio is constant, because the fine powder exhibits the constant shrinkage ratio. The green compacts having net shape can therefore be stably produced.

Referring to the method illustrated in Fig. 53, the fine powder 5 is conveyed by the conveyor 302 and is fallen from the conveyor 302 onto the vibrating mesh 303. The agglomerated particles of the fine powder 305 are disintegrated by the vibrating mesh 303 and are therefore not fallen in the form of lumps. The weighing instrument 306, positioned below the vibrating mesh 303, is provided with a container 304 which receives the fine powder 305. The weight of the fine powder 305 stacked on the container 304 is monitored to collect a predetermined amount of the fine powder 5.

During a stopping period of the vibrating mesh 305, the fine powder 5 virtually does not fall through the vibrating mesh 305. It is therefore possible by means of repeating ON and OFF of the vibration of the vibrating mesh 305 to very accurately control the dropping amount of the fine powder 5 into the container 304. Instead of measuring the weight, the volume of the fine powder may be measured. In addition, instead of the container 304, a rubber mold or a rubber mold provided with a guide frame may be located on the weighing instrument so as to weigh and fill the fine powder.

When the load from a punch(es) is relieved, a rubber mold restores its shape. A green compact can therefore be removed from the rubber mold. However, when the filling density of the fine powder in a rubber mold is very high, or when unevenness degree of a green compact is somewhat, a sufficient clearance between a green compact and a die may not be formed for enabling the removal of a green compact. In order to enable the withdrawal of a green compact in such cases as above, a rubber mold may consist of separated side parts 10a, 10b as shown in Fig. 54. Two or more parts of a rubber mold 10 may be divided when removing a green compact 320 from a rubber mold 10. Furthermore, a rubber mold 10 may have a cut plane 311 at a portion of the side wall.

When a green compact is withdrawn from the rubber mold 10, it is enlarged at the cut plane 311 so as to facilitate the withdrawal. In addition, the side portions 10a, 10b and the bottom 10c may be divided from each other. It is however to be noted that the rubber molds shown in Figs. 54 and 55 have the following disadvantages. The fine powder may be seized at the cut plane 311 or the divided parts of the molds. Furthermore, the rubber mold may be twisted during the compacting, resulting in non-uniform deformation of a green compact. The setting time of these rubber molds in a die is long.

In order to eliminate the disadvantages as described above, a clearance between the green compact and the die is preferably enlarged when the green compact is withdrawn from the rubber mold. The enlarging of the clearance can be carried out by means of applying pressure of, for example, gas to the inner surface of the rubber mold, and/or reducing the pressure of the outer surface of the rubber mold. By these measures, a pressure difference between the inner and outer surfaces of a rubber mold is created to enlarge the clearance.

Referring to Fig. 56, a cylindrical cover 312 is rigidly attached to the top of a rubber mold 310 having bottom. The rubber mold 310 and the cylindrical cover 312 are sealed therebetween. Pressurized gas having pressure of from 1 to 5 atmosphere is admitted into the cylindrical cover 312 so as to expand the rubber mold. A suction pipe 314, which is protruded in the rubber mold 310, is lowered so that the front end of the suction pipe 310 is pressed against the top of the green compact 320. The green compact is then sucked by the suction pipe 314. When the green compact is a

magnetic body, it may be attracted by an electro-magnet.

Referring to Fig. 57, the pressure applied to the outer surface of a rubber mold is reduced. A sealing cover 314 is pressed on the die 1 via the O rings 315b. The rubber mold 310 is pressed upwards on the sealing cover 314 by the lower punch 308. An O ring 308 is fitted around the lower punch 308 and between the lower punch 308 and the die 1. Therefore, when the gas is evacuated through the gas-evacuation channel 314a, the vacuum space 318 is created around the outer surface of the rubber mold 310. The rubber mold 310 therefore expands to enlarge the clearance between the rubber mold 310 and the green compact 320. The electro-magnet 317 attracts then the green compact 310.

After die-pressing, a rubber mold may be turned upside down, and the clearance between a green compact and the rubber mold may be created to fall the green compact.

The preliminary application of magnetic field may be carried out as described hereinabove and the die-pressing of powder or pre-compact filled at a high density carried out under no magnetic field. The apparatus for carrying out the second method is the one shown in Fig. 25, in which the magnetic coils 4 and its power source 55 are omitted or modified so that they only generate a low magnetic field and demagnetize the green compact. This apparatus has a simple construction in the case the parts 4 and 55 are omitted. The efficiency is high because the magnetic field is not applied during the compacting in a die-press machine, thereby shortening the pressing time. The demagnetization may be omitted, when the remaining magnetization does not cause cracking and the like of a green compact. The omission is therefore determined taking the shape and dimension of a green compact into consideration. The feature "no field" in the second method means that no provision for orienting, such as a coil, is used, but also means that the powder may be exposed to unavoidable magnetic field, such as the leakage flux from a pulse-magnetic field generator adjacent to the die-press machine, or geomagnetism.

The preliminary application of magnetic field causes the orientation of powder and enables, without application of magnetic field during die-pressing, to attain the magnetic properties of a green compact as good as in the conventional axial die-pressing. This may be sufficient for several applications. In the present invention, the compacting of powder in a direction perpendicular to the moving direction of a punch is realized and does not cause buckling of the powder particles, with the result that the preliminary orientation is not disordered by the movement of a punch. Contrary to this, when the die-pressing is carried out in the die-cavity without a rubber mold, the pressure of the punch is directed to the same direction as the orientation direction of the powder particles. In this case, buckling of the powder particles occurs, thereby disordering the orientation. In the present invention, the direction of the powder particles parallel to the moving direction of a punch is essentially maintained due to the effect of the rubber mold as described above. Incidentally, when the magnetic field is applied to the powder being compacted in a die-press machine good orientation is stably obtained with very slight variance of the orientation.

Back-up Plate

The back-up plate is elastic material, which is harder than the rubber mold, and is located between the rubber mold and one or both of the upper and lower punch(es).

Referring to Fig. 26, several embodiments of the back-up plate are illustrated.

When a rubber mold 10 located in a die 2 is directly pressed by the punches 1a and 1b, the rubber plastically flows into the clearances between the die 2 and punches 2a, 2b (Fig. 26(A)), particularly when the rubber is soft. The rubber is therefore caught in the clearances. The withdrawing of the punches 1a, 1b from the die 2 therefore becomes difficult. In addition, the rubber mold 10 may be damaged. A back-up plate 12, which consists of harder elastic material than the rubber mold, is therefore located between the upper punch 1a and the rubber mold 10, and another back-up plate 12 is located between the lower punch 1b and the rubber mold 10. The back-up plates 12 elastically deform by the pressing by the punches 1a, 1b and seals the clearances between the punches 1a, 1b and die 2. A back-up plate 12 may be provided only between the upper punch 1a and the rubber mold 10. In addition, as shown in Fig. 26(C), a recess may be formed on the edge of each punch 1a, 1b to attach there an annular back-up plate 12. Furthermore, as shown in Fig. 26(D), the back-up plates 12 may be attached to the recesses formed around the edges of a rubber mold 10. When the pressing pressure is very high, the back-up plate is preferably chamfered on the edges which face a punch and a die, to prevent plastic flow of the back-up plate in the clearance between the die and punch(es). The chamfered surface may be concave, convex, straight or "L" shaped.

Circulating Type Apparatus

Referring to Figs. 27 and 28, an embodiment of the apparatus according to the invention is illustrated by the top view and the side and partially cross-sectional view.

In this embodiment, the die is embodied as a rotary disc type-die with a plurality of cylindrical through-holes (hereinafter referred to as the "dies"). Only two through-holes are shown but there may be three or more. The motor 91 rotates the rotary die 2a so that the dies move around the circular passage. The upper and lower punches 1a, 1b are inserted

into each die from above and below, respectively, at position P_1 . The rubber mold 10s together with powder is filled into each die at position P_2 , where the mold loader 70 is set. A rubber mold 10 containing a green compact is removed from the rotary die 2a at position P_3 , where the removers 78, 84 are set. The rotary die 2a is rotated by the motor 91 so that each die passes through the positions P_2 , P_1 and P_3 , successively.

The rotary die 2a need not be totally made of expensive die steels but only at the contacting portions with the punches. Plastics, iron and the like can be used for the non-contacting portions so as to reduce the weight and cost of the rotary die 2a. The mold loader 70 is driven by two cylinders 71 and 80. The cylinder 70 reciprocates a hollow rod 79, on whose front end a suction piece is attached. A rubber mold 10 is loaded in the die 2 as shown in Fig. 28. The cylinder 70 is secured to the piston rod 82 of a cylinder 80 and is therefore lifted or lowered as a whole by the cylinder 80. When the cylinder 70 is in a lifted position as shown by the dotted line, a rubber mold 10 is sucked by the suction piece above the conveyer. While the cylinder 70 keeps the lifted position, the piston 79 advances up to a position above the die 2. The cylinder 71 is then lowered to position the rubber mold 10 into the die 2. The hydraulic units 76 and 81 drive the cylinders 70 and 80, respectively.

While the rotary die 2a rotates, the stationary cam 75 guides the liftable bottom 2d which is inserted in the die 2. The movement of the liftable bottom 2d is determined by the upper surface-profile of the stationary cam 75 as illustrated in Fig. 29. First, during the die-pressing, the die is completely remote from the stationary cam 75 (Fig. 29(A)). The liftable bottom 2d then rides on the skirt portion of the stationary cam 75 (Fig. 29(B)) and further rises along the slanted surface (Figs. 29(C) and (D)). When the liftable bottom 2d arrives at the flat top of the stationary cam 75, the rubber mold 10, in which a green compact has been compacted, arrives at the same level as the upper surface of the rotary die 2a. At this moment, the rubber mold 10 is in the position P_3 (Fig. 28). The liftable bottom 2d then lowers to open the die cavity, where uncompacted powder can again be loaded.

As shown in Fig. 27, a conveyor 40, whose end is in the vicinity of position P_2 , conveys the rubber molds in which the powder is filled. A powder-feeder 42, a cover-mounting device 89 and a magnetic-pulse generator, e.g., the electromagnetic coils 4a, are provided at the different positions of the conveyor 40, as shown in Fig. 27.

A second conveyor 140 is provided at such a position that its end is in the vicinity of the position P_3 . Along with the rotary movement of rotary disc 2a, the rubber molds 10 are guided along the removing plate 78 and slide on the stationary table 84, so that the rubber molds 10 are transferred to the second conveyor 140.

Powder-filling in Inert Atmosphere

The powder of rare-earth magnet is preferably filled or loaded into a rubber mold in an inert atmosphere, thereby preventing oxidation of the powder during the filling or loading. In this embodiment, the methods illustrated in Figs. 2 and 3 are carried out in the chamber 95 (Fig. 30) filled with inert gas as shown in Fig. 30. A cover 10h is tightly fitted on the rubber mold 10 in the inert gas atmosphere. The rubber mold 10 is then set in a die-press machine as shown in Fig. 36(B). After die-pressing, the rubber mold 10 is removed from the die-press machine as shown in Fig. 30(C). The method illustrated in Fig. 30 is advantageously applied for the rare-earth alloy powder crushed by a jet mill and in a non-oxygen atmosphere, for example, a nitrogen atmosphere having oxygen content of less than the limit detectable by analysis. Such powder has an extremely low oxygen content so that the magnet produced using such powder exhibits excellent magnetic properties. The powder is, however, extremely active so that it is readily flammable in air. Its handling is therefore difficult. The method illustrated in Fig. 30 can extract the excellent magnetic properties from the highly active powder as described, while enhancing the magnetic properties due to the compacting in a rubber mold.

The green compact produced by the above-described methods are sintered by the known method, and is then heat-treated, if necessary, so as to produce a sintered magnet. The magnet powder and resin may be compacted together to produce a resin-bonded magnet.

Method and Apparatus using Circuit

Figure 31 illustrates an embodiment of the fourth method. In this embodiment, a rubber mold 10i consists of a cylindrical body without a bottom. Its bottom is, however, closed with the rotary die 2a. A portion of the rotary die 2a therefore constitutes the bottom of the rubber mold. While the rubber molds 10i move successively along the circular passage along with the rotation of rotary die 2a, the powder is fed by a feeder 42 into each rubber mold 10i; the filling density of the powder is enhanced by vibration and compacting by a pusher; a cover 10u (not shown in Fig. 31 but shown in Fig. 32) is inserted at position C, the magnetic field is applied by means of the electromagnetic coils 4a to orient the powder; die-pressing by the die-pressing apparatus is carried out with or without the application of magnetic field; the cover 10u is removed at position F; and the green compact is removed by the removing device 62.

The removed cover 10u is returned by the linear transporter 140 (Fig. 32) to its inserting position C. The linear transporter 140 comprises a rail which guides the suction piece 140a which is in turn connected to a suction pump. A motor (not shown) is movably mounted on the rail and displaces the suction piece 140a to which the cover 10u is

secured.

The removing device 62 comprises an arm 64, such as an electromagnet, capable of swivelling around the shaft 65 at a specified angle. When the electromagnet is energized and is swivelled, the magnetically anisotropic green compact is attracted to the arm 64 positioned above the conveyor 40. The arm 64 performs such a movement that it is swivelled back toward the position above the other conveyor 66 and is then de-energized. The green compact is therefore placed on the conveyor 66.

Since the rubber mold reverts to the initial shape after the compacting, an annular clearance 10r is formed around the green compact and between it and the rubber mold. The annular clearance 10r is sufficiently large for removing the green compact from the rubber mold by the magnetic attraction.

The conveyor 66 is driven by a step motor 67 which is controlled by the control unit 50. This control unit 50 controls the above-described operation of the electromagnet 64 as well as the conveyor 66, i.e., the intermittent movement upon the placing of a green compact on it.

In Fig. 31, a cleaning device consisting of the parts 150 - 153 is provided. These are an air-piston 150, an air-unit 151, an electromagnet 152, and a power source 153 for energizing the electromagnet 152. When a green compact is removed from the rubber mold, the electromagnet 152 is displaced above the rubber mold and is then energized by the power source 153. The powder remaining in the rubber mold is attracted by the electromagnet 152 thus cleaning the rubber mold.

According to the method as illustrated in Fig. 31, the die-press machine 60 carries out only the compacting with or without the application of magnet field, that is, neither setting nor removal of a rubber mold are carried out in the die-pressing machine 60. This method is therefore more efficient than the method where die-pressing and setting and removal of a rubber mold are all carried out in the die-press machine. One pressing cycle is therefore short in the former method. The apparatus as shown in Fig. 31 is appropriate for large-scale production.

When the endless-type die-pressing method as illustrated in Fig. 31 is used for large-scale production of magnets, the time required for respective steps may be as follows.

- (a) Powder feeding, vibration, pushing (at position A) and movement up to step (b): 15 seconds
- (b) Attachment of cover (at position C): 5 seconds
- (c) Application of magnetic-field pulse (at position D): 15 seconds
- (d) Die-pressing (at position E): 15 seconds
- (e) Removal of cover (at position F): 5 seconds
- (f) Removal of a green compact and cleaning of a rubber mold (at position G): 10 seconds

Since the longest operation takes 15 seconds, and, further, the conveying time from each of the steps (a) through (f) to the next step is 2 seconds, a time period for producing one green compact is 17 seconds.

Next is described the time required for the respective steps of the conventional die-pressing method, in which the powder is filled into the die-cavity of a die-press machine.

- (a) Powder feeding by a feeder: 10 seconds
- (b) Lowering of an upper punch (the lower punch shunts when feeding the powder, and then lowers from the shunting position into the die): 5 seconds.
- (c) Pressing (application of static magnetic field, compacting by the upper and lower punches, and application of inverse magnetic field): 27 seconds.
- (d) Adjusting of shunting: 5 seconds
- (e) Removal of a green compact: 10 seconds

The total time of the steps (a) through (e) is 57 seconds. The first step (a) cannot be initiated until all of the steps (a) through (e) are finished. Therefore, as long as 57 seconds is necessary for producing one green compact.

Preferred Embodiments in view of Properties of Magnets

In the present invention, the powder is preferably fed into a rubber mold and is filled at a high density at the same place. If the powder-feeding by a guide frame 100 is carried out at a different place from the high densification place by a pusher or the like, the guide plate must be transferred from the former position to the latter position. As a result, the number of the guide plates required increases, and hence the structure of the pressing apparatus is complicated.

The powder should not be fed directly from the feeder into a rubber mold but should be fed via mesh and another container; that is, the powder is first fed to the mesh, which sieves the aggregates of powder, and then is fed to another container. After accurately weighing the powder, it is fed from the container into a rubber mold. Since the flowability of the magnet powder is very poor, it is difficult to feed an accurate amount of the powder from the feeder into the rubber

mold. The method of feeding the powder via the mesh and container is therefore preferred for feeding the magnet powder.

The circulating apparatus is preferably located in a chamber filled with inert gas, so as to prevent oxidation of the powder, such as $\text{Nd}_2\text{Fe}_{14}\text{B}$ or Sm-Co powder. The chamber may be in the form of a dome or an annular tunnel covering the rotary die.

A green compact of magnet material may be demagnetized until or after it is withdrawn from a rubber mold. The demagnetization is however unnecessary when the magnetization of the green compact is low.

According to a preferable demagnetization method, a green compact is demagnetized in a rubber mold while load from a pusher(s) is relieved but is still applied on the green compact. This demagnetization method drastically lessens the stress due to the magnetization and hence danger of cracking of a green compact.

Wet Die-pressing

The above-described techniques are applied to the method according to the invention, i.e., the wet die-pressing, with the use of a rubber mold and a slurry of powder and solvent i.e., water or organic solvent. The proportion of the powder to solvent is not limited but is preferably from 2 to 4 weight parts of solvent to from 8 to 6 weight parts of powder. A feature employed in the wet-die pressing with the use of a rubber mold is that the rubber mold is open at the top, because the water or the like must be withdrawn from the mold interior through a filter and a suction channel of the upper punch, during the pressing with the use of the upper punch. Since the rubber mold is open at the top, the compacting is less isostatic than in the conventional pseudo CIP. Note, however, this CIP is a dry type, in which the powder is completely surrounded by the pressure medium, i.e., the rubber. But a satisfactory orientation is attained due to the presence of a solvent which reduces the friction between the powder particles. Furthermore, the pressure from the lateral portion of the rubber mold promotes removal of the solvent and, hence, the draining speed of the solvent is high. The pressing efficiency is therefore very high.

The slurry may be preliminarily injected into a rubber mold outside a die-press machine and the rubber mold is then loaded in a die-press machine; or, the rubber mold may be preliminarily loaded in a die-press machine and the slurry may be injected into the rubber mold. The injection of slurry into a rubber mold may be carried out by the following methods: preliminarily evacuating the rubber mold to a vacuum and the slurry is then injected; after injecting the slurry into a rubber mold, the slurry is exposed to vacuum or reduced pressure; or the slurry is injected into a rubber mold at a high pressure. These methods prevent the blow holes from remaining on the surface of a rubber mold and hence prevent failure of products due to the blow holes.

Referring to Fig. 33 an embodiment of the wet die-pressing apparatus according to the present invention is illustrated. The wet die-pressing apparatus comprises: a power source 30 for generating the magnetic field; a hydraulic unit 31; hydraulic cylinders 32, 33; a filter 34 consisting of filter paper or cloth; rolls 35 for winding the filter 34; suction channel 36 formed through the upper punch 1a; a water-suction pump 38; a motor 39 for driving the water-suction pump; and a feeder 42 of the powder materials. The apparatus also comprises parts other than the above mentioned; these are denoted by the same reference numerals as shown in Fig. 16.

The suction channel consists of through-holes having a diameter of 1mm or more so as to enhance the suction efficiency of the pump. The feeder 42 is connected with a source of the pressurized air-source (not shown), if it is necessary to feed the slurry with pressure. When the feeder 42 completes feeding of slurry into the rubber mold 10, the feeder shunts outside the compacting region of the punches 1a, 1b. The hydraulic unit 31 feeds the pressure medium into the hydraulic cylinder 32 and forces the upper punch 1a and the filter 34 to move down until the filter 34 covers the open top of the filter 34 to move down until the filter 34 covers the open top of the rubber mold 10. The lower punch 1b is then pushed upwards. Simultaneously, the suction pump 38 is operated to suck the water through the suction channel 36. When the suction of water is completed, the lower punch 1b is further pushed upwards. When the space between the upper punch 1a and the die 2 is closed, the power source 30 energizes the electromagnetic coils 4, which generates then the magnetic flux permeating through the upper and lower punches 1a, 1b. The compacting of powder by the upper and lower punches 1a, 1b is then carried out. Upon completion of the die-pressing, the steps, which are in reverse sequence to those described above, are carried out. The rolls 35 are rotated to reel the filter 34 and to expose an unused section of the filter 34.

Figure 34 illustrates the essential part of another embodiment of the wet-type die-pressing apparatus according to the present invention. This apparatus is the same as illustrated in Fig. 33, except that the filter 34 is a ceramic filter. The continuous pores in the ceramic, which communicate its inner and outer surfaces with one another, are utilized as water-sucking channels. After die-pressing, high-pressure air is blown through the pores to remove the powder remaining there and hence to prevent clogging. The ceramic filter 34 is therefore used a number of times. A plaster filter, which is very inexpensive and is easily available, can be used for the ceramic filter 34. A filter, which has a two-layer structure for enhancing the durability and water-suction property, can also be used for the ceramic filter 34.

Referring to Fig. 35, operation of the apparatus with the use of a ceramic filter is illustrated.

First, the upper punch is lowered from the upper limit to the lower limit, and then stops. At virtually the same time as the descending movement of the upper punch stops, the power source is switched on. Immediately thereafter, the suction pump is energized, that is, a positive magnetic field is applied with the aid of the power source to the powder to orient it, while the water is removed by the suction pump from the slurry during the orientation. Simultaneously with the energization of the vacuum pump, the lower punch is pushed upwards to remove water from the slurry. The lower punch is further pushed upwards until the upper limit so as to compact the powder to the desired density. The power source is then switched off and is then again switched on to generate a negative magnetic field which is weaker than the positive magnetic field. This negative magnetic field reduces the remaining magnetization of a green compact to facilitate its subsequent handling. During the operations as described above, the suction pump is kept energized to further remove the water. The suction pump, power source and lower punch are all de-energized. After this, the upper punch is pushed upwards and the pressurized gas is blown through the filter to remove the clogging. The above series of operations is controlled by a microcomputer or sequence apparatus. For example, 20 seconds is necessary for one cycle consisting of the above steps, while in the conventional wet die-pressing approximately 90 seconds are necessary for one cycle. In the present invention, the period of one cycle is shorter than in the conventional method, because the water remove speed is high and the friction between the powder and die is excluded.

A noticeable phenomenon, discovered in the wet-die pressing with the use of a rubber mold, is that a green compact may crack when the powder is filled lower than the upper surface of a rubber mold. Another noticeable phenomenon is that, when the upper surface of powder filled in a rubber mold, particularly in one having a concave configuration of the upper surface, rises higher than the upper surface of the rubber mold, the rising portion of powder is pushed out of the die cavity onto the upper surface of the rubber mold, thereby forming a burr. In order to decrease incidence of these phenomena described above, the slurry is preferably injected into a rubber mold such that the profile of its upper surface is coincident with the profile of the lower surface of the upper punch. Preferred methods for such injection are: increasing the water content of the slurry to as high as 60% by weight or more; and using a guide-plate 105 shown in Fig. 36. The slurry is injected through the inlet 107 into the rubber mold 10. Subsequently, the guide-plate 105 is moved in the direction of the arrow to rub off the slurry, or is lifted up.

Another phenomenon discovered is that the slurry and air in the cavity of the rubber mold are liable to form bubbles on the wall surface of a rubber mold, and, further, surface defects, such as indentations and the like, are formed on a green compact. A preferred method for decreasing the incidence of such phenomenon is to add into the slurry such defoaming agents as methyl alcohol and ethyl alcohol. Another preferred method is to treat, before or after filling a rubber mold with slurry, the inside of a rubber-mold cavity with reduced pressure. A rubber mold may be placed in a gas-tight chamber and exposed to vacuum in this chamber.

Figure 37, illustrates an apparatus for injecting the slurry, adjusting the upper profile of the slurry, and treating the rubber mold with reduced pressure.

A rubber mold 10 is fixed to the pedestal 130 and side-holder 131. A vacuum-container 132 made of acryl resin is fixed gas-tightly to the side-holder 131 via the packing 133. A piston 135 is gas-tightly and reciprocally mounted in the central top aperture of the container 132 via the packing 134. A collar 137 is secured to the piston 135 at a place outside the vacuum-container 132. A spring 136 is fitted between the collar 137 and the top of vacuum-container 132 to normally bias the piston 135 upwards. A stopper 142 is attached to the front end of the piston 135, and a conduit 138 for feeding the slurry is secured in the stopper 142. The conduit 138 is gas-tightly attached to the vacuum-container 132 via the packing 139 and is displaced in and retracted from the vacuum-container 132. The conduit 138 therefore moves vertically along with the vertical movement of the piston 135. A detachable plate 140, which is secured to the stopper 142, is strengthened by a partition plate 141, which consists of material, such as fluorine plastic whose water-wettability is small. The strengthened plate 140 has in the central top part a passage which can be closed by the electromagnetic valve 149. The lower surface of the partition plate 141 has the same shape as the lower surface of the upper punch.

The apparatus shown in Fig. 37 is operated as follows.

The electromagnetic valve 149 is closed. The partition plate 141 is attracted by the piston 135 and both are lifted into a position shown by the dotted lines. The opening 145 for introducing air is closed, and the vacuum container 132 is evacuated through the opening 144. The piston 135 is then pushed downwards so as to press the strengthened plate 140 against the rubber mold 10 and hence to bring the plate 140 into contact with the rubber mold 10. The electromagnetic valve 141 is then opened by remote control outside the vacuum container 132. The slurry is then fed through the conduit 138 into the rubber mold 10 with the aid of high-pressure gas. Air is then introduced into the vacuum container 132 through the opening 145. The piston 135 is then lifted above to lift the vacuum container 132 by hanging it on the stopper 142.

The slurry may, however, not be injected as illustrated in Figs. 33 and 37 but may be preliminarily compacted and then filled in a rubber mold 10 as illustrated in Fig. 38.

A piston 151 slides on the walls 152, 153 of a slurry-extruder 160, compresses the slurry 15 and extrudes it through the outlet of the slurry-extruder 160 as the pre-compact 15a. The pre-compact 15a is extruded onto the retractable

bottom 159 and is then cut by lowering a cutter 158. After cutting, the pusher 157 is lowered by sliding it on the cutter 158 and the wall 161. The pusher 157 is stopped when its bottom surface strikes the upper surface of the pre-compact 15a. The retractable bottom 159 is then retracted, and the pre-compact is pushed into the rubber mold 10s, 10k by means of the pusher 157.

Figure 39 illustrates a circulating type apparatus for wet-die pressing. The same parts as those shown in Figs. 22 and 28 are denoted by the same reference numerals. A slurry-filling device shown in Fig. 28 or a loading device of a pre-compact shown in Fig. 29 is installed at position A. The filling of slurry and vacuum-suction are carried out at position A by the source of high-pressure air 166. Alternatively, only the filling of slurry is carried out at position A and the vacuum suction is carried out at position B by the vacuum-pump 165. Vacuum chambers 132 may be installed at positions A and/or B to locate the rubber molds therein.

Rubber Molds

A rubber mold for forming a hollow green compact according to the present invention comprises a mandrel which is harder than the other portions of the rubber mold. If the mandrel of a rubber mold is softer than the other portions of the rubber mold, the mandrel 10m (Fig. 40) shrinks in the radially inner direction when pressure is applied by the punch(es) to the rubber mold. When the punch(es) is later retracted, the load applied to the rubber mold 10 and powder is relieved, with the result that the mandrel 10m, which has been shrunk once, pushes the green compact and expands to enlarge the hole of a green compact 5. The green compact 5 may therefore crack. The rubber mold according to the present invention lessens the shrinkage of the mandrel 10m and hence prevents the cracking of a green compact. The hollow green compact can be either radially or axially oriented.

A rubber mold for forming a hollow green compact may be provided with two mandrels 10m, 10m'. The upper punch 1 is provided with a recess 1a' for guiding the mandrel 10m. The mandrels 10m, 10m' may consist of metal.

Preferable structure of the rubber mold used according to the present invention are now described. In this description the upper, lower and side portions of a rubber mold are referred to as the top, bottom and side wall, respectively. In addition, at least the surface part of the above portions in contact with the powder should consist of materials, or have hardness, as described hereinafter.

According to one of the preferable rubber molds, at least either the top or bottom is harder than the wall part. If, on the contrary, the wall part is harder than the top and/or bottom, such incidence as is schematically shown in Fig. 42 occurs. That is, the deformation of the side wall 10s incurs a considerable shrinkage of the (soft) bottom 10k to form wrinkles on it. These wrinkles act as the starting points of cracks 5'. In addition, the soft bottom 10k is liable to seize the powder, and the friction between the bottom 10k and the powder is great. When the pressure of a punch(es) is relieved, the bottom 10k tends to be restored to its original shape and hence to deform in the reverse direction from that during the compacting. At the reverse deformation, since the seizure between the bottom 10k and the green compact has occurred during the compacting, the green compact 5' follows the deformation of bottom 10k. The green compact 5' may therefore crack.

When the bottom 10k is of the same hardness as the side wall 10s, then the cracks are formed as described with reference to Fig. 42, when the degree of deformation is high. The preferable rubber mold therefore consists of a hard bottom and/or top made of metal or hard rubber or resin.

According to another preferable rubber mold, at least either the top or bottom has a thickness (t, unit-mm) defined by $t = 16h/D$ (h is thickness of a green compact in mm, and D is the positive root of cross-sectional area (mm^2) of the green compact). The thickness of a bottom and the thickness of a green compact mean those in the pressing direction by a punch(es). The cross-sectional area of a green compact is the area of the cross section in the direction perpendicular to the pressing direction by a punch(es). As the area of a green compact greater (smaller value for the right side of the formula above), the inverse deformation force of a rubber mold becomes greater, thereby making a green compact to crack easily. The thickness of the top and/or bottom is therefore decreased. The effect of the thickness (h) to prevent cracks is illustrated in Fig. 42. The bottom 10k is compressed by the upper punch 1a generating the pressure P_a (Fig. 43) and the lower punch 1b generating the pressure P_d in the other direction. The pressure P_c is the shrinking stress reducing the cross-sectional area of the side wall 10s and the green compact. The wrinkles are generated by the pressure P_c . The thinner the bottom 10k, the greater is the pressure P_a and P_b , thereby holding stronger the bottom 10k. When the holding force exceeds the pressure P_c , wrinkles do not generate.

The coefficient "16" of the above formula was obtained from the following experiments. That is, the coefficient "16" was confirmed to be critical for the incidence of cracks of green compacts formed with the use of rubber molds shown in Figs. 36 (E) and (F) and having dimensions of $30 \times 30 \times 5 \text{ mm}$ and $h/D = 0.17$. Powders of Nd-Fe-B and Fe-Co magnets were compacted under the pressure of 1.0 ton/cm^2 .

The above-described two preferable rubber molds can be embodied as examples shown in Fig. 44. In this drawing, the hatched part consists of metal or hard rubber. The thickness of the top and/or bottom satisfying the above equation is referred to as "thin".

In Fig. 44(A), the top 10u, side wall 10s and bottom 10k consist of soft rubber, soft and hard rubber, or metal.

In Fig. 44(B), the top 10u, side wall 10s and bottom 10k consist of soft rubber, soft and hard rubber, or metal.

In Fig. 44(C), the thin top 10u, side wall 10s and bottom 10k consist of soft rubber, soft and hard rubber, or metal.

In Fig. 44(D), the thin top 10u, and the integral side wall 10s and bottom 10k consist of soft rubber.

In Fig. 44(E), the top 10u, and the integral side wall 10s and bottom 10k consist of hard rubber or metal and soft rubber, respectively.

In Fig. 44(F), the top 10u, and the integral side wall 10s and thin bottom 10k consist of soft rubber.

In Fig. 44(G), the top 10u consists of hard rubber or metal, and the integral side wall 10s and thin bottom 10k consist of soft rubber.

In Fig. 44(H), the thin top 10u, and the integral side wall 10s and thin bottom 10k consist of soft rubber.

In Fig. 44(I), the top 10u, side wall 10s and bottom 10k consist of hard rubber or metal, soft and hard rubber, or metal.

In Fig. 44(J), the side wall 10s and bottom 10k consist of soft and hard rubber or metal, respectively, and the bottom 10k is rigidly inserted in the recess formed in the side wall 10s.

In Fig. 44(K), the side wall 10s and bottom 10k consist of soft and hard rubber or metal, respectively, and the bottom 10k is rigidly inserted in the recess formed in the inner side surface of the side wall 10s.

In Fig. 44(L), the top 10u is provided with a projection protruding downwards and consists of hard rubber or metal. The side wall 10s and the bottom 10k consist of soft and hard rubber or metal, respectively.

The top 10u consisting of metal as shown for the example in Fig. 44(E) can be embodied in the upper punch of a die-press machine. In addition, the bottom 10k consisting of hard metal can be embodied in the lower punch of a die-press machine.

The above described relationship of hardness and thickness of the portions of a rubber mold are not preferable for an elongated green compact, because the phenomena occurring during the compacting are just opposite to the one described above. The elongated compact is the one having a length two times greater than the width thereof. The flat compact is the one having a width two times greater than the length thereof. The width is defined as the positive square root of cross-sectional area of a green compact. In the compacting of a flat green compact, the compression from the wide opposite ends, where the area is greater than the side surface, is decisive for preventing the cracks. Contrary to this, in the compacting of an elongated green compact, the compression of powder from the side surface is decisive for preventing the cracks, specifically the laminar cracks shown in Fig. 58. It is therefore preferred to construct a rubber mold for a flat green compact such that either top or bottom or both of a rubber mold, which face(s) the punch(es) of a die-press machine be harder than the side portion of the rubber mold. It is therefore preferred to construct a rubber mold for an elongated green compact such that the side portion of a rubber mold be harder than either top or bottom or both of a rubber mold.

Preferably, a rubber mold has a dual-layer structure, such that a portion of a rubber mold in contact with the fine powder consists of hard material and the other portion, distant from the die cavity, consists of soft rubber. In this dual-layer structure, the fine powder is not seized by the hard rubber, thereby easing to withdraw a green compact from a rubber mold.

The harder rubber herein indicates that is harder than the softer rubber by at least 10% in terms of hardness A stipulated in JIS. However, when the so determined hardness is greater than 100, the above relationship is not observed but the harder rubber has a hardness A of 100.

The dual-layer rubber mold can be produced by molding or injection molding the hard and soft materials. The side, top and/or bottom portion can have the dual-layer structure. The dual-layer structure can be provided by applying hard material on the inner surface of a rubber mold, which has been preliminarily produced. The dual-layer structure may be such that the portion of a rubber mold in contact with the fine powder has a low coefficient of friction. Lubricant, such as molybdenum disulfide and the like, may be incorporated in the rubber or resin. Alternatively, polyethylene tetrafluoride (PTFE) and other resin having a low coefficient of friction may be used as the inner layer of the rubber mold.

In the production apparatuses of a magnet described above, the rubber mold 10 and the die 2, which is detachably mounted in the circuit, may be circulated together.

In an embodiment where the rubber molds are circulated by rotation through the positions where such members (42, 4a, 60, 65, 132) of the apparatus for treating the magnet powder are arranged, a motor must be intermittently activated and stopped accurately at the positions, particularly the die-pressing position. At this position, the punch and the die must be aligned very accurately, so that the requirement accuracy in the stopping position of the rubber mold can be very strictly observed.

According to a preferred embodiment which eases such strict requirement for accuracy in activating/stopping the motor, the circuit has the configuration of an equilateral polygon or scalene polygon, and said members are located at the apex region and/or side region of said equilateral or scalene polygon. There is also provided a means for transporting the rubber mold in a linear movement between the adjacent apexes. The linear movement can be easily attained by means of a hydraulic cylinder or the like. A particular advantage of the scalene polygonal configuration is that the distance between the adjacent apexes, where the successive two treatments are carried out, can be appropriately

determined taking into consideration the size of said members, treatment time at each step and the like. One or more treatments may be carried out at each apex.

According to a preferred embodiment of the polygonal circuit, it is of quadrilateral configuration. In this case, a means for transporting a rubber mold may comprise rails extending between the adjacent apexes and at least two
 5 palettes slidably mounted on the rails and supporting the rubber mold and the die. In this embodiment, said members are arranged in such a manner that by the circulating movement of the transporting means the magnet powder is transferred to the successive treating positions.

Figures 46 through 51 show preferred embodiments of the production apparatus of magnet.

The palette 201 (Fig. 46) is a quadrilateral plate for carrying the rubber mold 10 and the die 2. The palette 201 is
 10 carried on the rail 241 via the ball bearings 242. The palette 201 is provided with downward projections 243, in which the ball bearings 242 are rotatably mounted. Instead of the ball bearings, a wheel 241 (Fig. 47) may be guided along the rail 248. The wheels 248 may be secured at the four corners of the palette 201.

The palette 201 (Fig. 47) comprises a movable stage 202 inserted vertically slidably therein and supporting the
 15 die 2 on its top surface. The movable stage 202 is resiliently mounted on the body of the palette 201. For this resilient mounting, the springs 245 are inserted between the horizontally protruding portion of the movable stage 202 and the L-shaped section rigidly secured to the bottom of the palette 201.

The feeder of powder, the removing device, the magnetic-field generator, the precompacting device, and the die-
 20 press machine are linearly arranged on the straight passage at positions A, B, C, D, and E (Fig. 48). A palette (not shown) therefore moves from A position via C, D and E to B position and stops at the respective positions for the respective treatment. The order of arrangement of the feeder and the like is not restricted.

The upper punch 1a (Fig. 46) lowers to be brought into contact with the movable stage 202, while compressing
 25 the springs 245. When the movable stage 202 further lowers, it pushes the metal plate 240. The compacting of the powder then starts. The resilient mounting as is shown in Fig. 46 therefore mitigates the force of the upper punch 1a and hence prevents trouble from occurring due to excessive load during the die pressing.

The operation of the apparatus shown in Fig. 49 is now described.

The guide plate 214 covers the palette 202. The arm 206 is secured to the guide plate 214, and the pneumatic
 30 piston 208 is secured on the arm 206 via a vertical column 207. The pneumatic cylinder 208 is provided with horizontally movable piston rod 208' and actuates the piston rod 208'. A hopper of powder 209 is secured on the piston rod 208' and is hence horizontally displaced relative to the palette 202. The pneumatic cylinder 210 actuates the pusher 211 and is horizontally displaced by the pneumatic cylinder 208. The four palettes 201 are carried by the frame 232.

The driving means of the arm 206 is denoted by the reference numeral 230.

When the palette 202 is positioned directly below the guide plate 214, the arm is driven downwards to press the
 35 guide plate 204 against the rubber mold. Then, the powder is fed from the hopper 209 via the feeder 205 which is tightly attached to the guide plate 204, into the rubber mold. The pneumatic cylinder 208 is then actuated to retract the hopper 209 and simultaneously advance the pusher onto the position directly above the guide plate 204. The pneumatic cylinder 210 is then actuated to lower the pusher 211, which then slides along the side wall of the guide plate 204 and presses the powder into the rubber mold. The pusher 211 is then elevated. The arm 206 is elevated to retract the hopper 209 and guide plate 204 upwards. The palette 202 is then transferred from the position A to the position B.

In position B, the pulse coil 215 is carried on the frame which is held by the vertical columns 213. The pulse coil
 40 215 is lowered by a hydraulic cylinder 214 to cover the die. The cover 216 is simultaneously lowered to shield the die so as to prevent the powder from scattering outside the die during the magnetization. After the magnetization, the pulse coil 215 is lifted. The palette 202 is then transferred from position B to position C.

At position C, the die-press machine comprising the upper punch 219 and the hydraulic cylinder 217 is located.
 45 These members are carried by a frame which is held by the vertical columns 218. The pressing as is illustrated with reference to Fig. 46 is carried out at position C.

The palette 202 is transferred from position C to position D, where the green compact 228 is taken out of the rubber
 50 mold by the method as is described with reference to Fig. 31. The magnetic pole in the form of a pin 223 is lowered by the pneumatic cylinder 222 to magnetically attract the green compact 228 which has been compacted in the rubber mold 231. The pneumatic cylinder 222 is secured on the arm 224 which is swivelled around the shaft 225 by motor 226. The green compacts 228 are conveyed by the conveyor 227.

Figs. 50 and 51 illustrate a means for transferring the palette 201. A motor 260 for driving the transferring of the
 55 palette 201 is secured to the upper frame 270. The upper frame 270 is supported by the lower frame 268. The gear 267 is driven directly by the motor 260, and a chain 268 is wound around the gear 267 and the other gear 261 which is secured to the upper frame 270. The chain 268 is provided with clicks 255.

The palettes 201 are also provided with the clicks 252 at the four corners at such a position that they 252 can be
 60 engaged with the clicks 255 of the chain 268. The palettes 201 are carried via the wheels on the rails 251, which are extended along each side of the upper frame 270.

The palettes 201 can therefore be transferred between, for example, positions A and B. When the click 255 is

displaced at the extreme position, for example position B in Fig. 50, it pushes the palette 201 so that an appropriate clearance is formed therebetween 201 and 255, thereby making it possible to move the click 255 along the gear 267 toward the lower side of the chain 268. The click 255 further moves and stops at position A. The click 255 stops there until the time of the next transfer.

The present invention is hereinafter described by way of Examples.

Reference Example.

The rubber mold shown in Fig. 45 was used. The cover 10u was made of metal. The side wall 10s and the bottom 10k were made of integral soft urethane rubber (hardness 40 in JIS A). The back-up plate 12 made of hard urethane rubber (hardness 90) was located under the bottom 10k, so as to prevent the rubber of the bottom from being seized in the clearance between the die and the punch(es). The dimension of mold cavity was 30mm, 30mm and 5mm.

The raw materials used were commercial strontium carbonate (SrCO_3) and commercial ferric oxide (Fe_2O_3). The respective raw materials were blended in molar proportion of 1:5.9 and were then crushed and mixed for 5 hours. The mixture was calcined at 1270°C for 1 hour. The calcined sample was roughly crushed by a stamp mill to provide an average particle diameter of 4 μm and subsequently finely milled by a ball mill to provide an average particle-diameter of 0.7 μm . The finely milled powder was dried in air, and subjected to dry pressing. The so-provided fine powder was filled in the rubber mold 10s, 10k by means of imparting vibration and pressure by a pusher, so that filling density of from 0.6 to 2.8g/cm³ (13-58%) was attained. The rubber mold 10s, 10k was covered with the cover 10u and the magnetic field of 3.184x10⁶ A/m (40kOe) was applied five times each for 5u seconds. Subsequently, the rubber mold was located in a die-press machine. The axial pressing was carried out under pressure of 0.8ton/cm² and magnetic field press-forming was carried out under pressure of 0.8ton/cm² and magnetic field of 955200 A/m (12kOe). The obtained green compacts were sintered at 1200°C.

The magnetic properties of the sintered compacts and the quality of the green compacts are given in Table 1.

Table 1

Filling Density (g/cc)	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2
Br (kG) Tx10 ⁻¹	3.80	3.93	4.02	4.02	4.02	3.92	3.82	3.61	3.02
(BH) _{max} (MGOe) kJ/m ³	(3.44) 27.4	(3.63) 28.9	(3.80) 30.2	(3.80) 30.2	(3.80) 30.2	(3.60) 28.7	(3.43) 27.3	(3.06) 24.4	(2.14) 17.0
iHc (kOe) A/mx10 ⁻⁶	(2.8) 0.229	(2.8) 0.229	(2.8) 0.229	(2.8) 0.229	(2.8) 0.229	(2.8) 0.229	(2.9) 0.231	(2.9) 0.231	(3.0) 0.239

The filling density of 0.6g/cc corresponds to natural filling.

Example 1 (Wet ferrite magnet)

Commercial strontium carbonate (SrCO_3) and commercial ferric oxide (Fe_2O_3) were blended in molar proportion of 1:5.9 and were then milled by a ball mill for 6 hours. The mixture was calcined at 1260°C for 2 hours. After calcining, the sample was roughly crushed and then finely milled to provide average particle-diameter of $0.75\mu\text{m}$. The obtained fine powder was rendered to slurry having slurry concentration of 71% (weight percentage of the ferrite powder based on the total weight of the slurry).

Arc-shaped green compacts as shown in Fig. 10 were produced using the wet-die press machine shown in Fig. 25 and provided with a filter 34 made of cloth or paper, a vacuum suction device and a slurry injection device and also using the wet-die press shown in Fig. 26 and provided with ceramic filter 34.

The methods employed for slurry injection were of injecting slurry from upper portion of the rubber mold preliminarily located in a die (Fig. 25), or of injecting slurry into the rubber mold outside the press machine and then setting the rubber mold in the press machine. The filling method employed in the conventional wet method, i.e., injecting of slurry into the die through an aperture formed in the side wall of the die, was not employed.

The respective steps of the compression forming were finely adjusted so that they do not interfere with one another and, further, excess idle time is almost avoided.

The compression forming was repeated one hundred times for each density and each filling method. For comparison purpose, the conventional parallel die-pressing (without rubber mold) was carried out one hundred times. In order to measure the density and magnetic properties of the sintered magnets, sampling of each sample was carried out for each five press cycles and the samples were sintered at 1235°C for 1.5 hours. The samples for measuring the magnetic properties were cut from the arc-shaped sintered magnets and were subjected to measurement with a BH tracer. The average magnetic properties are given in Table 2.

Table 2

Filter	Generation of Cracks (%)	Density (g/cm ²)	iHc (kOe) A/m	Br (kG) $T \times 10^{-1}$	(BH) _{max} (MGOe) kJ/m ³	Filling Method	Remarks
Paper, Cloth	5	4.96	(2.8) 222880	4.12	(4.0) 31.8	within die	Comparative
Ceramics	4	4.97	(2.8) 222880	4.11	(4.0) 31.8	within die	Comparative
Paper, Cloth	1	4.96	(2.8) 222880	4.32	(4.4) 35.0	outside die	Inventive
Ceramics	1	4.97	(2.8) 222880	4.31	(4.4) 31.8	outside die	
Paper, Cloth	1	4.97	(2.8) 222880	4.31	(4.4) 31.8	within die	
Ceramics	1	4.96	(2.8) 222880	4.32	(4.4) 31.8	within die	

As is apparent from Table 2, cracks are decreased, and Br and (BH)_{max} are increased according to the present invention.

Example 2

The slurry used in Example 1 was dried and then the aggregates of powder were disintegrated for 1 hour in a ball mill, to provide dry powder. Measuring the bulk density of the dry powder revealed to be 0.80g/cm³. This dry powder was filled in a rubber mold made of silicone rubber, 23.95mm in outer diameter, 12mm in inner diameter, and 10mm in height. The filling methods were the combination of the steps chosen from the group as mentioned below. The amount of the powder was so adjusted that it was filled up to the top edge of the rubber mold. Influence of the powder bulk-density in the rubber mold (g/cm³) upon the molding under the magnetic field was investigated.

Filling Methods

- (1) The rubber mold is placed on the vibrator, and the filling density is enhanced by vibration.

- (2) The rubber mold is loaded in a tapping machine, and the filling density is enhanced by vibration.
 (3) Magnetic field is applied to the powder in a rubber mold to enhance the filling density due to the attraction force of the magnetic field and the attraction force of the magnetized particles of the powder.
 (4) Powder granulated under magnetic field is used. The granulating degree is such that the particles of the granulated powder easily disintegrated under the magnetic field.
 (5) Relatively strongly granulated and oriented powder was formed under a magnetic field.
 (6) Magnetic powder was preliminarily compression-shaped at a pressure of a few tens kg/cm² to enhance the filling density.

Then the powder, whose filling density was enhanced by the above-mentioned method, was subjected five times to application of pulse magnetic field of 3.184×10^6 A/m (40kOe) for 5 μ seconds for each time. The green compacts were sintered at 1230°C for 2 hours. The quality of the green compacts and the maximum energy product of the sintered compacts are given in Table 3.

Table 3

Filling Density	0.8	0.9	1.0	1.1	1.2	1.3	1.4
Cracks, Crazing	C	B	A	A	A	A	A
Deformation	C	B	B	A	A	A	A
$(BH)_{\max}$ (MGOe)	(4.4)	(4.4)	(4.4)	(4.4)	(4.4)	(4.4)	(4.4)
kJ/m^3	35.0						

The criterion and cracks was as follows:

A: Virtually neither cracks nor fracture

B: 5% or less of cracks and fracture

C: More than 5% of cracks and fracture

Example 3

Commercially available raw material for preparing the ferrite-magnet slurry was used in the procedure reported in the Reference Example. The green compacts obtained by the respective methods were sintered. The magnetic properties of the sintered magnets are given in Table 4.

Table 4

Example	Br (kG) $\times 10^{-1}$	iHc (kOe) A/m	$(BH)_{\max}$ (MGOe) kJ/m^3
3	4.52	(2.95) 234820	(4.86) 38.7
Reference	4.30	(2.98) 237208	(4.40) 35.0

The magnetic properties of this inventive example are better than those of the Reference Example, given in Table 1. Since ferrite powder having excellent magnetic properties was used in these examples, the magnetic properties are excellent even in the comparative example. Since $(BH)_{\max}$ of the present example is higher than that of the Reference example by approximately 10%, it is clear that extremely excellent $(BH)_{\max}$ is obtained by using the magnet powder having excellent magnetic properties.

Claims

1. A production method of a magnet comprising: filling a slurry (15) containing magnet powder in a rubber mold (10) which consists of rubber at least in its side portion (10s), in or outside a die-press machine which is provided with an upper punch (1a), a filter (34) and a water-suction channel (36) formed in the upper punch (1a); locating the filter (34) between the upper punch (1a) and the open upper portion of the rubber mold (10); and compacting the rubber mold (10) and the slurry (15), thereby sucking the solvent through the filter (34) and the water-suction channel (36).
2. A production method of a magnet according to claim 1, wherein prior or subsequent to filling the slurry, the inside of the rubber mold (10) is subjected to degassing treatment under vacuum (132).
3. A production method according to claim 1 or claim 2, wherein the rubber mold (10) comprises at least a top and bottom, in which at least one of the top and the bottom has a thickness t , in mm, defined by $t \leq 16h/D$, where h is thickness of the green compact, and D is a positive square root of cross-sectional area of the green compact, and $D > 2h$.
4. A production method according to claim 1 or claim 2, wherein the rubber mold (10) comprises at least a top and bottom, in which at least one of the top and the bottom has a thickness t , in mm, defined by $t \geq 16h/D$, where h is thickness of the green compact, D is a positive square root of cross-sectional area of the green compact, and $2D < h$.
5. A production method according to claim 1 or claim 2 wherein the rubber mold (10) comprises a mandrel (10m) which is harder than the other portions (10s,k) of the rubber mold (10).
6. A production method according to any preceding claim wherein the production of a green compact is carried out on a circuit (2a), which is circulated and in which the rubber mold (10) is mounted.
7. An apparatus for producing a green compact comprising: a high-density filling device comprising a feeder (42) for feeding the powder into the rubber molds (10) as indicated in claim 1 or a loader (125) of a preliminarily compacted powder and a means (41, 121, 212, 225, 228, 231) for enhancing the filling density of the powder; a diepress machine; and device (64) for removing a green compact from each rubber mold (10).
8. An apparatus for producing a green compact according to claim 7, further comprising a magnetic-field generator (4a).
9. An apparatus for producing a green compact according to claim 7 or claim 8, further comprising a chamber having inert-gas atmosphere therein and locating the members of the apparatus therein.
10. An apparatus for producing a green compact according to claim 7 or claim 8, further comprising a circuit (2a) which is circulated, and in which the rubber molds are mounted, and along which the members of the apparatus are successively arranged.
11. An apparatus for producing a green compact according to claim 7 or claim 8, further comprising a straight passage for arranging separately the members of the apparatus therealong, a rail and a reciprocating means for reciprocating a palette (202) on which the rubber mold is detachably mounted.
12. An apparatus for producing a green compact according to claim 7 or claim 8, wherein said members of the apparatus are located at either apex region or side region of a mold-supporting means (232) having a configuration of equilateral or scalene polygon, and further palettes (202) supporting the rubber molds are transported in a linear movement between the adjacent locations (A, B, C and D) of said members.

Patentansprüche

1. Verfahren zur Herstellung eines Magneten, welches umfaßt:
Einfüllen einer Magnetpulver enthaltenden Aufschlämmung (15) in eine Gummipreßform (10), bei der zumindest der Seitenabschnitt (10s) aus Gummi besteht, innerhalb oder außerhalb einer Warmpreßvorrichtung, die mit einem oberen Formeisen (1a), einem Filter (34) und einem im oberen Formeisen (1a) ausgebildeten Wasserabsaugkanal

(36) versehen ist; Anordnen des Filters (34) zwischen dem oberen Formeisen (1a) und dem offenen oberen Abschnitt der Gummipreßform (10); und Verdichten der Gummipreßform (10) und der Aufschlammung (15), wodurch das Lösungsmittel durch den Filter (34) und den Wasserabsaugkanal (36) abgesaugt wird.

- 5 2. Verfahren zur Herstellung eines Magneten nach Anspruch 1, wobei die Innenseite der Gummipreßform (10) vor oder nach dem Einfüllen der Aufschlammung einer Entgasungsbehandlung im Vakuum (132) unterzogen wird.
- 10 3. Herstellungsverfahren nach Anspruch 1 oder Anspruch 2, wobei die Gummipreßform (10) mindestens eine Oberseite und eine Unterseite umfaßt, wobei die Oberseite und/oder die Unterseite eine Dicke in mm aufweisen, die durch $t \leq 16h/D$ definiert wird, worin h die Dicke des Grünlings ist, D die positive Quadratwurzel der Querschnittsfläche des Grünlings ist, und $D > 2h$ ist.
- 15 4. Herstellungsverfahren nach Anspruch 1 oder Anspruch 2, wobei die Gummipreßform (10) mindestens eine Oberseite und eine Unterseite umfaßt, wobei die Oberseite und/oder die Unterseite eine Dicke in mm aufweisen, die durch $t \geq 16h/D$ definiert wird, worin h die Dicke des Grünlings ist, D die positive Quadratwurzel der Querschnittsfläche des Grünlings ist, und $2D < h$ ist.
- 20 5. Herstellungsverfahren nach Anspruch 1 oder Anspruch 2, wobei die Gummipreßform (10) einen Dorn (10m) umfaßt, der härter als die anderen Teile (10s, k) der Gummipreßform (10) ist.
- 25 6. Herstellungsverfahren nach einem der vorstehenden Ansprüche, wobei die Herstellung des Grünlings auf einer Kreisbahn (2a) erfolgt, die zirkuliert, und in der die Gummipreßform (10) angebracht ist.
- 30 7. Vorrichtung zur Herstellung eines Grünlings, welche umfaßt: eine Einrichtung zum Einfüllen mit hoher Dichte, die eine Beschickungseinrichtung (42) zum Einfüllen des Pulvers in die Gummipreßformen (10) nach Anspruch 1 oder eine Ladeeinrichtung (125) für das vorverdichtete Pulver und eine Einrichtung (41, 121, 212, 225, 228, 231) zur Verbesserung der Füllichte des Pulvers umfaßt; eine Warmpreßvorrichtung; und eine Einrichtung (64) zur Entnahme des Grünlings aus jeder Gummipreßform (10).
- 35 8. Vorrichtung zur Herstellung eines Grünlings nach Anspruch 7, die außerdem einen Magnetfeldgenerator (4a) umfaßt.
9. Vorrichtung zur Herstellung eines Grünlings nach Anspruch 7 oder Anspruch 8, die außerdem eine Kammer mit einer Inertgasatmosphäre im Inneren und das Anordnen der Teile der Vorrichtung darin umfaßt.
- 40 10. Vorrichtung zur Herstellung eines Grünlings nach Anspruch 7 oder Anspruch 8, die außerdem eine Kreisbahn (2a) umfaßt, die zirkuliert und in der die Gummipreßformen angebracht sind, und entlang der die Teile der Vorrichtung nacheinander angeordnet sind.
- 45 11. Vorrichtung zur Herstellung eines Grünlings nach Anspruch 7 oder Anspruch 8, die außerdem einen geraden Durchgang, entlang dem die Teile der Vorrichtung getrennt angeordnet sind, eine Schiene und eine sich hin- und herbewegende Einrichtung zur Hin- und Herbewegung einer Palette (202) umfaßt, auf der die Gummipreßform lösbar angebracht ist.
- 50 12. Vorrichtung zur Herstellung eines Grünlings nach Anspruch 7 oder Anspruch 8, wobei die Teile der Vorrichtung an jedem Scheitelpunkt oder Seitenbereich der Einrichtung (232) zum Halten der Form angebracht sind, die die Konfiguration eines gleichseitigen oder schiefwinkligen Polygons hat, und weitere Paletten (202), die die Gummipreßformen tragen, in einer Linearbewegung zwischen den benachbarten Stellen (A, B, C und D) der Teile befördert werden.

Revendications

- 55 1. Procédé de fabrication d'un aimant consistant à: introduire une pâte (15) contenant une poudre magnétique dans un moule en caoutchouc (10), qui est constitué de caoutchouc au moins dans sa partie latérale (10s), dans ou à l'extérieur d'une machine de matriçage qui est équipée d'un poinçon supérieur (1a), d'un filtre (34) et d'un canal (36) d'aspiration de l'eau formé dans le poinçon supérieur (1a); positionner le filtre (34) entre le poinçon supérieur (1a) et la partie supérieure ouverte du moule en caoutchouc (10); et de comprimer le moule en caoutchouc (10)

et la pâte (15) de manière à aspirer ainsi le solvant à l'intérieur du filtre (34) et du canal (36) d'aspiration de l'eau.

2. Procédé de fabrication d'un aimant selon la revendication 1, selon lequel avant ou après l'introduction de la pâte, l'intérieur du moule en caoutchouc (10) est soumis à un traitement de dégazage sous vide (132).

3. Procédé de fabrication selon la revendication 1 ou 2, selon lequel le moule en caoutchouc (10) comprend au moins une partie supérieure et une partie inférieure, au moins l'une des parties supérieure ou inférieure possédant une épaisseur, en mm, définie par $t \leq 16h/D$, h étant l'épaisseur du compact à vert et D la racine carrée positive de la surface en coupe transversale du compact à vert, et $D > 2h$.

4. Procédé selon la revendication 1 ou 2, selon lequel le moule en caoutchouc (10) comprend au moins une partie supérieure et une partie inférieure, et selon lequel au moins l'une des parties supérieure et inférieure possède une épaisseur t en mm, définie par $t \geq 16h/D$, h étant l'épaisseur du compact à vert, D la racine carrée positive de la surface en coupe transversale du compact à vert et, $2D < h$.

5. Procédé de fabrication selon la revendication 1 ou 2, selon lequel le moule en caoutchouc (10) comprend un mandrin (10m) qui est plus dur que les autres parties (10s, k) du moule en caoutchouc (10).

6. Procédé de fabrication selon l'une quelconque des revendications précédentes, selon lequel la fabrication d'un compact à vert est exécutée dans un circuit (2a), qui est entraîné en circulation et dans lequel le moule en caoutchouc (10) est monté.

7. Dispositif pour fabriquer un compact à vert, comprenant : un dispositif de remplissage à haute densité comportant un dispositif d'alimentation (42) pour amener la poudre dans les moules en caoutchouc (10) comme indiqué dans la revendication 1 ou un dispositif de chargement (125) servant à charger une poudre tassée de façon préliminaire et des moyens (41, 121, 212, 225, 228, 231) pour améliorer la densité de remplissage de la poudre; une machine de matriçage; et un dispositif (64) pour retirer un compact à vert de chaque moule en caoutchouc (10).

8. Dispositif pour fabriquer un compact à vert selon la revendication 7, comprenant en outre un générateur de champ magnétique (4a).

9. Dispositif pour fabriquer un compact à vert selon la revendication 7 ou 8, comprenant en outre une chambre contenant une atmosphère de gaz inerte et positionnant les éléments du dispositif dans la chambre.

10. Dispositif pour fabriquer un compact à vert selon la revendication 7 ou 8, comprenant en outre un circuit (2a), qui est entraîné en circulation et dans lequel les moules en caoutchouc sont montés et le long duquel les éléments du dispositif sont disposés successivement.

11. Dispositif de production d'un compact à vert selon la revendication 7 ou 8, comprenant en outre un passage rectiligne pour disposer séparément les éléments du dispositif le long de ce passage, un rail et des moyens de déplacement en va-et-vient pour déplacer en va-et-vient une palette (202), sur laquelle le moule en caoutchouc est monté de façon amovible.

12. Dispositif de production d'un compact à vert selon la revendication 7 ou 8, dans lequel lesdits éléments du dispositif sont situés au niveau de la région sommitale ou au niveau d'une région latérale de moyens (232) de support de moules, possédant la configuration d'un polygone équilatéral ou scalène, et d'autres palettes (202) supportant les moules en caoutchouc sont transportées selon un déplacement linéaire entre les emplacements adjacents (A, B, C et D) desdits éléments.

Fig. 1 (A)

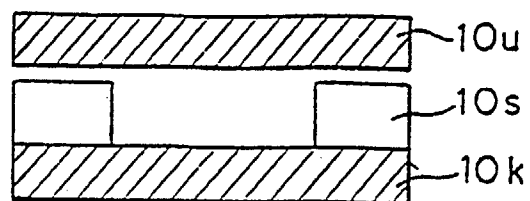


Fig. 1 (B)

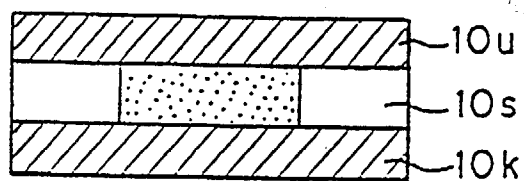


Fig. 1 (C)

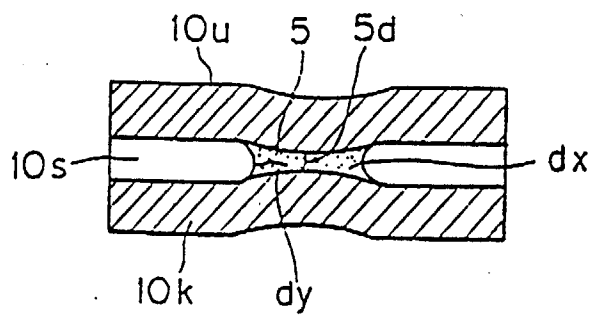


Fig. 2(A)

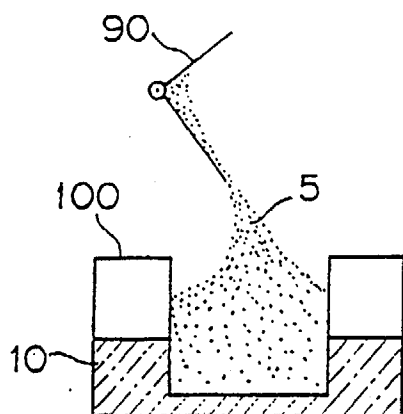


Fig. 2(B)

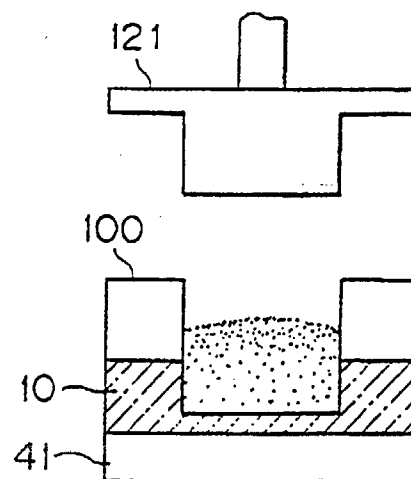


Fig. 2(C)

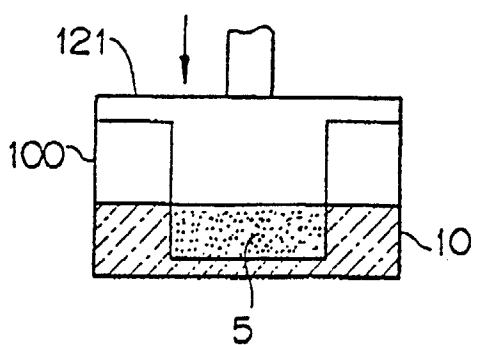


Fig. 2(D)

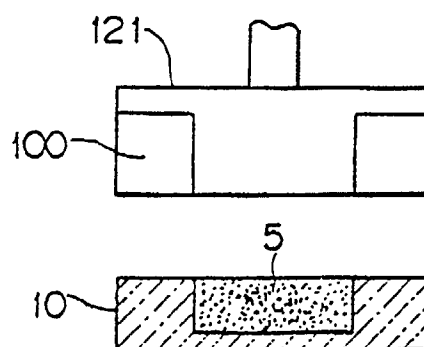


Fig. 3(A)

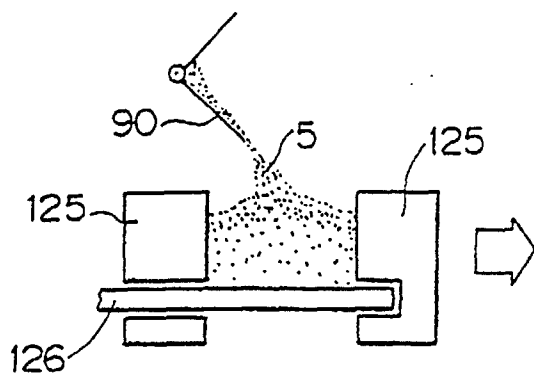


Fig. 3(B)

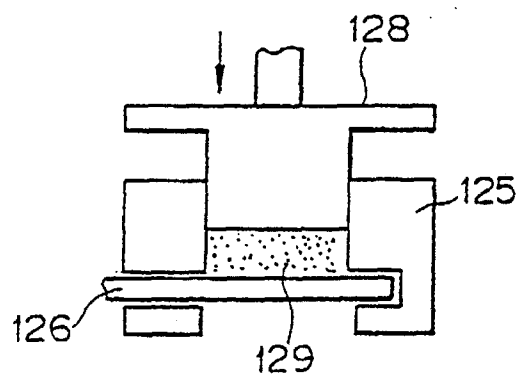


Fig. 3(C)

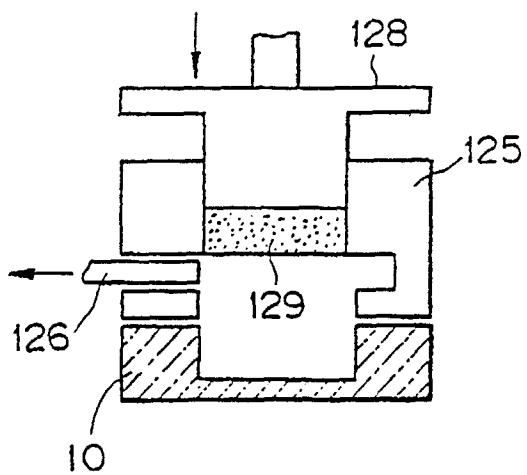


Fig. 3(D)

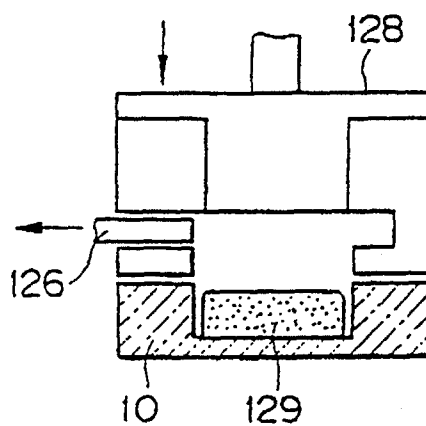


Fig. 4

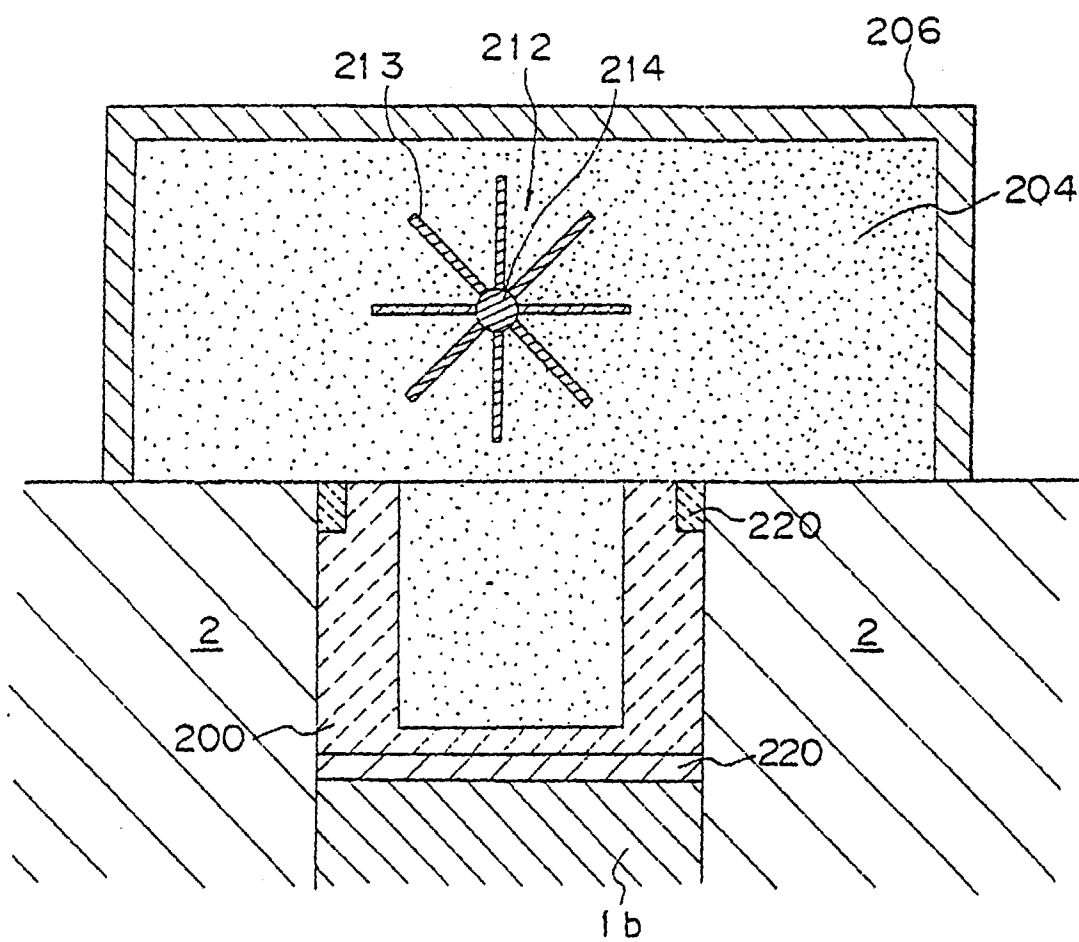
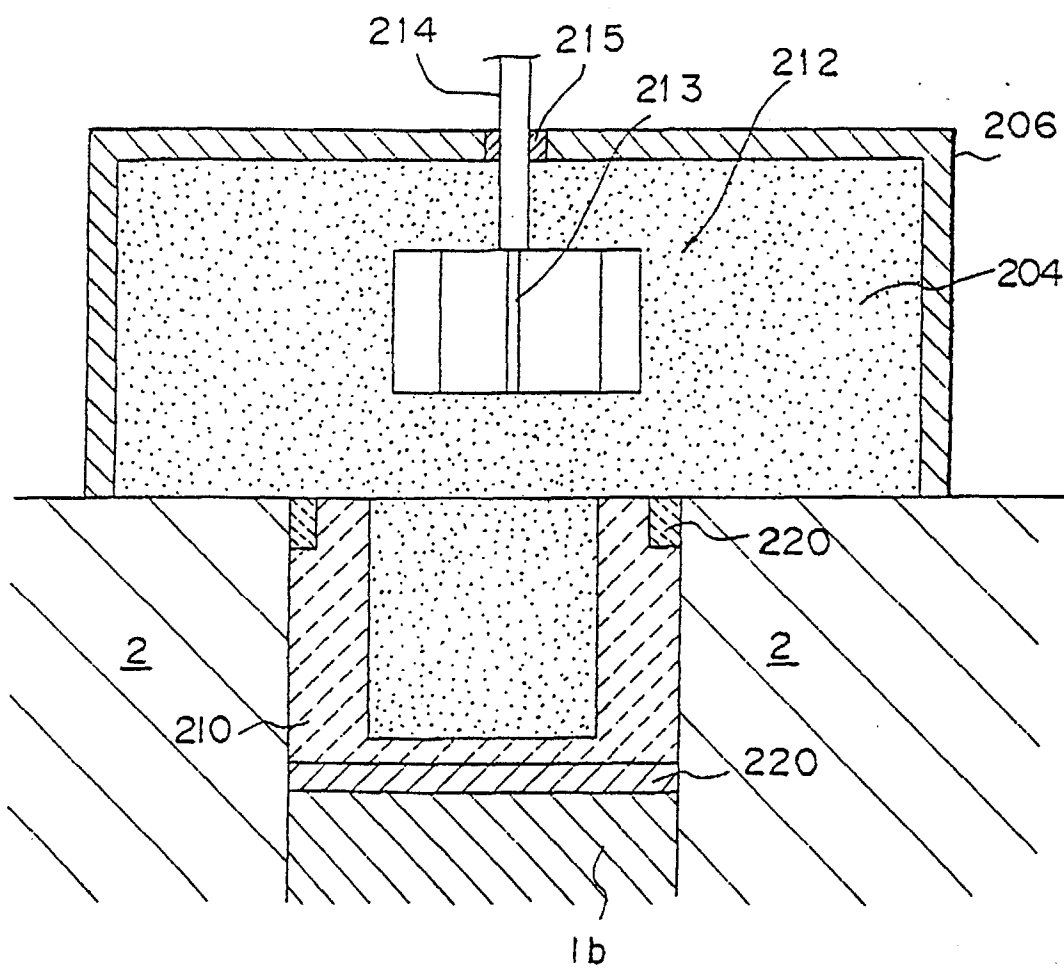


Fig. 5



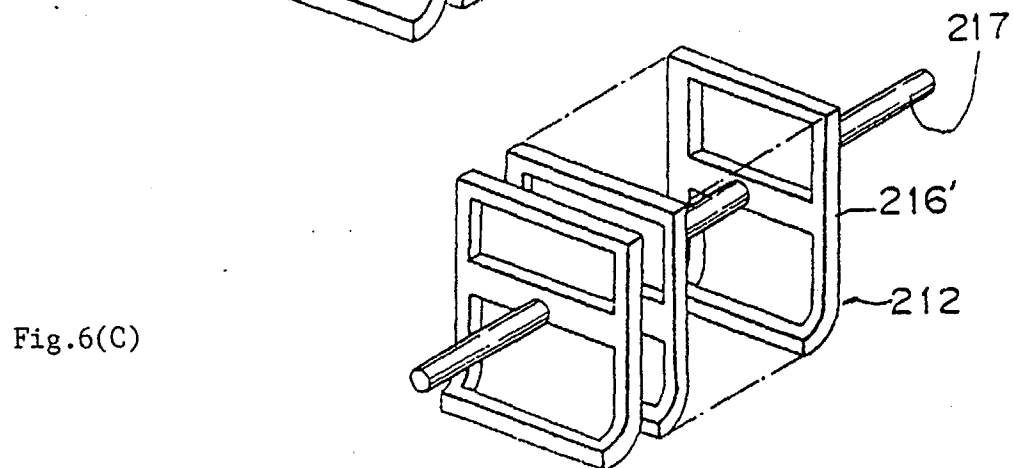
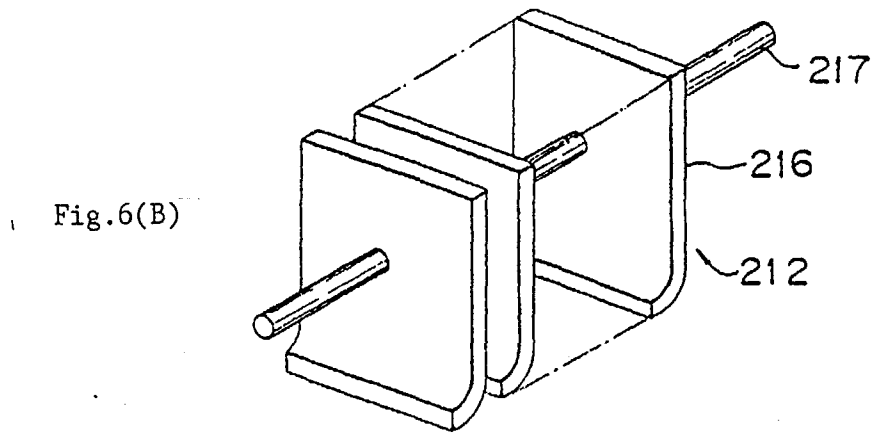
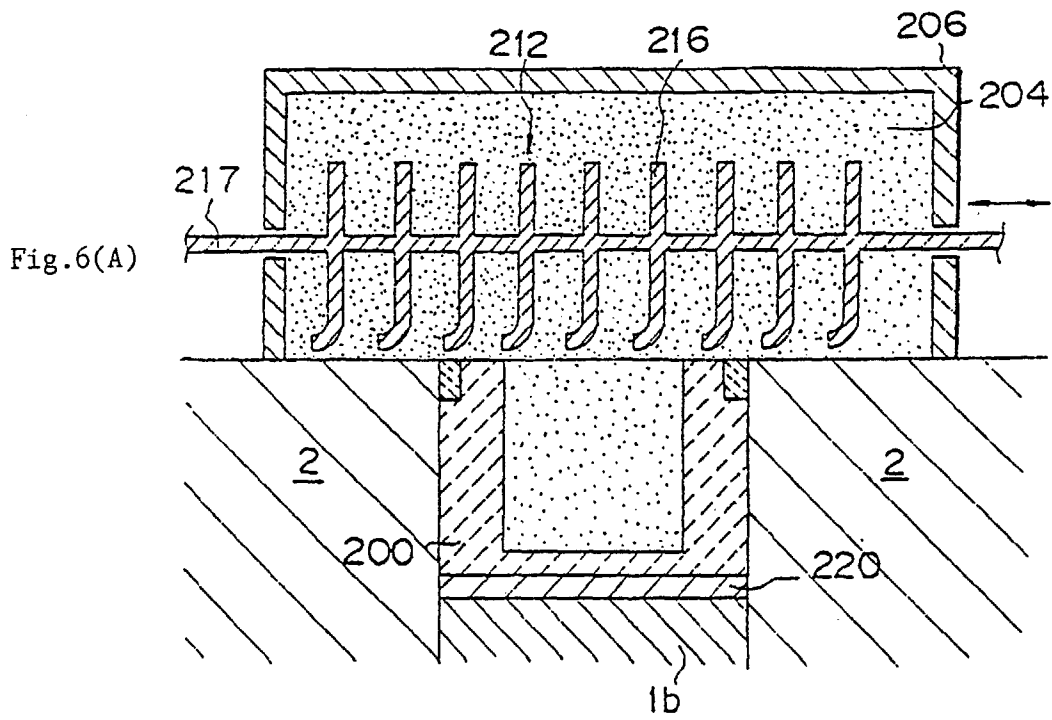


Fig. 7

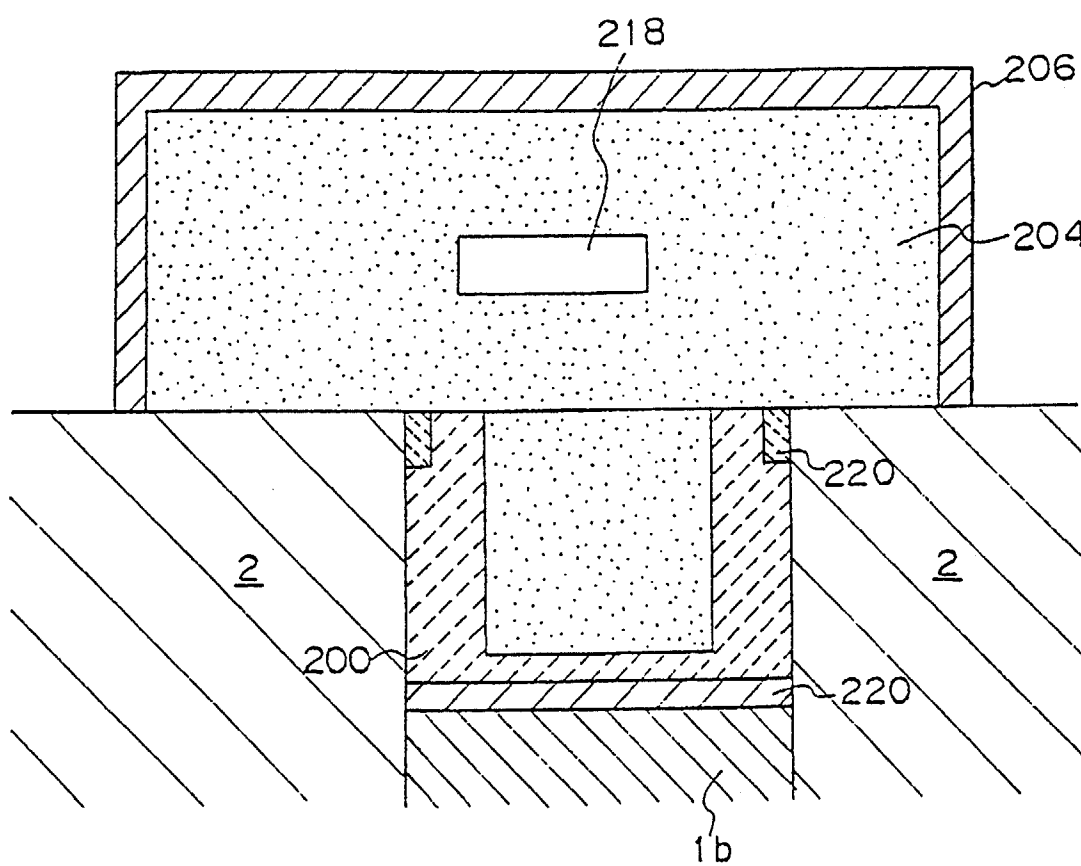


Fig. 8

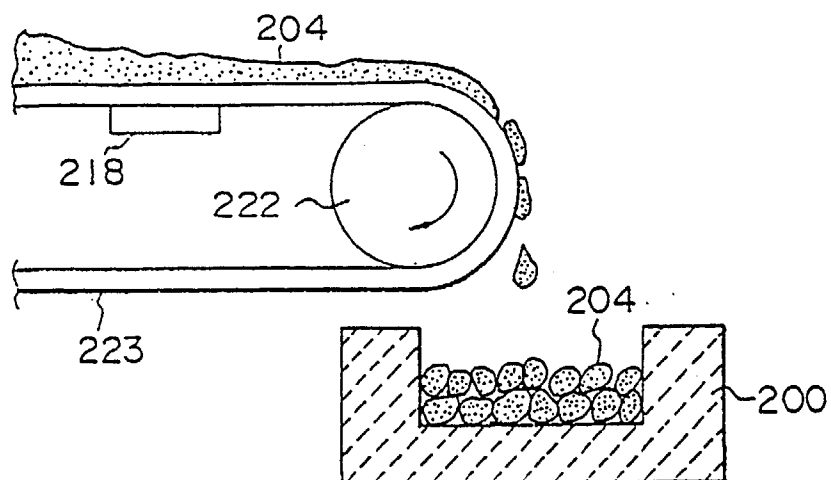


Fig. 9

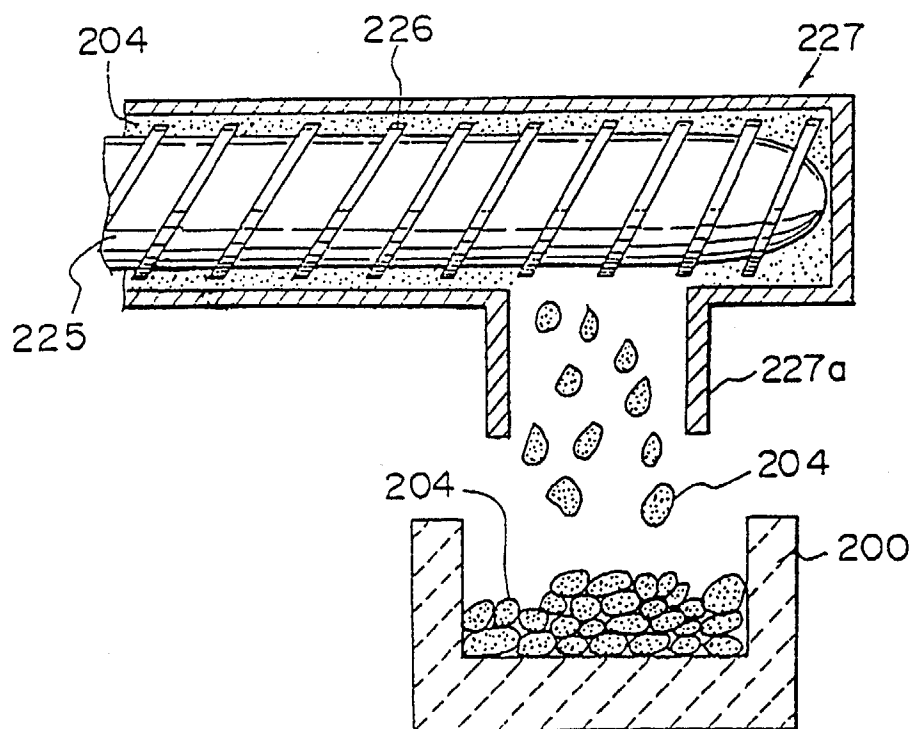


Fig. 10

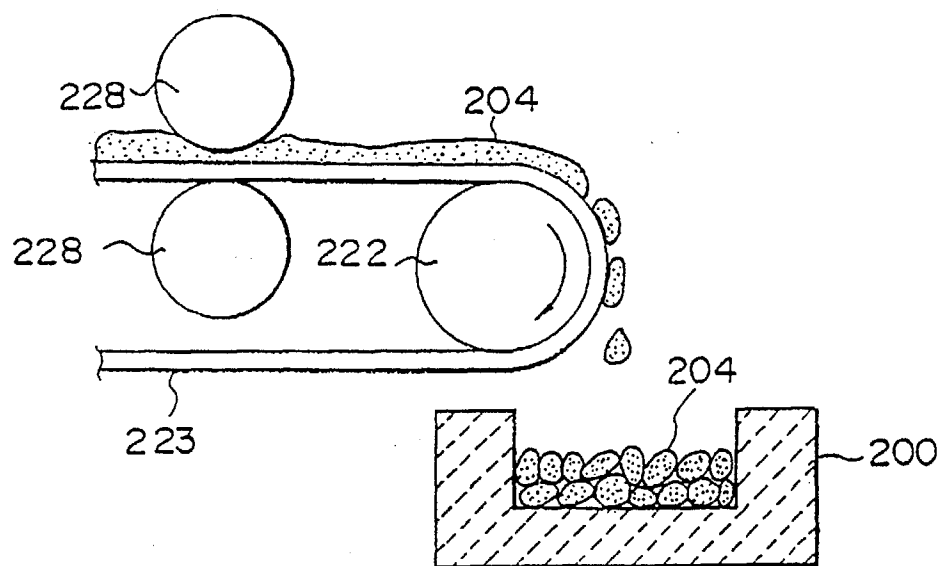
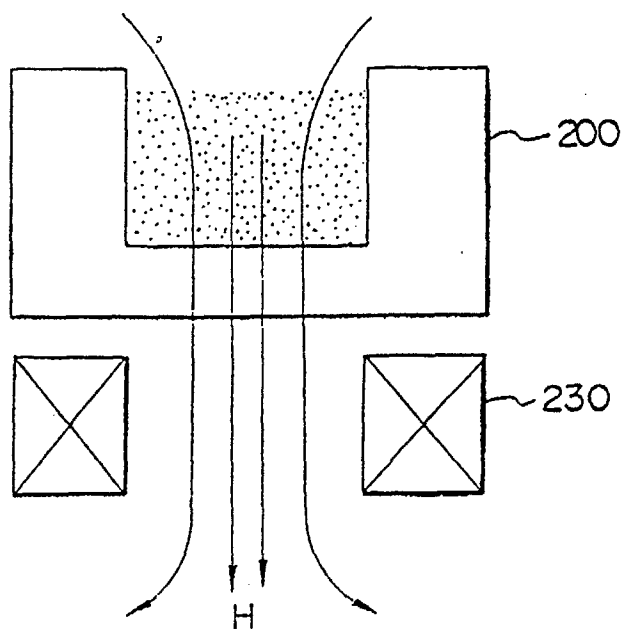
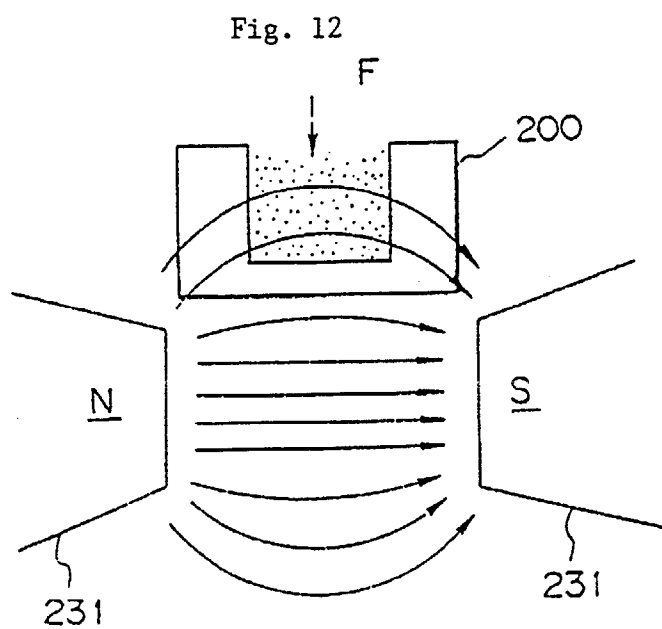


Fig. 11





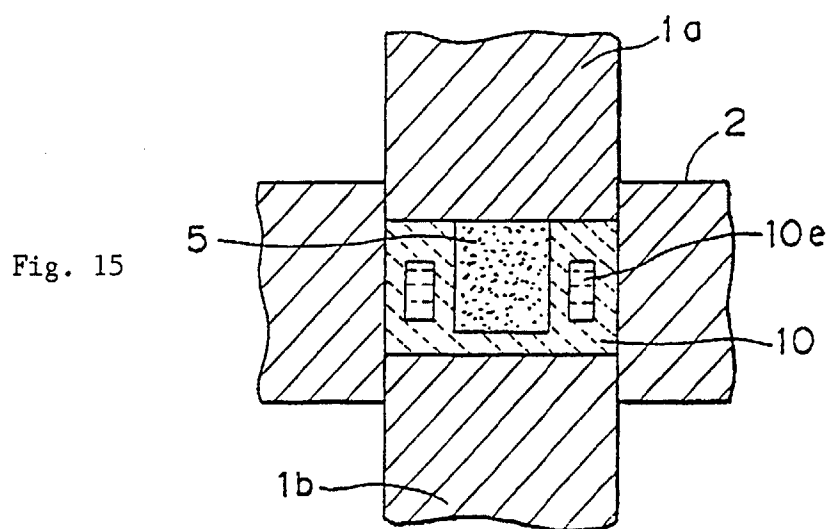
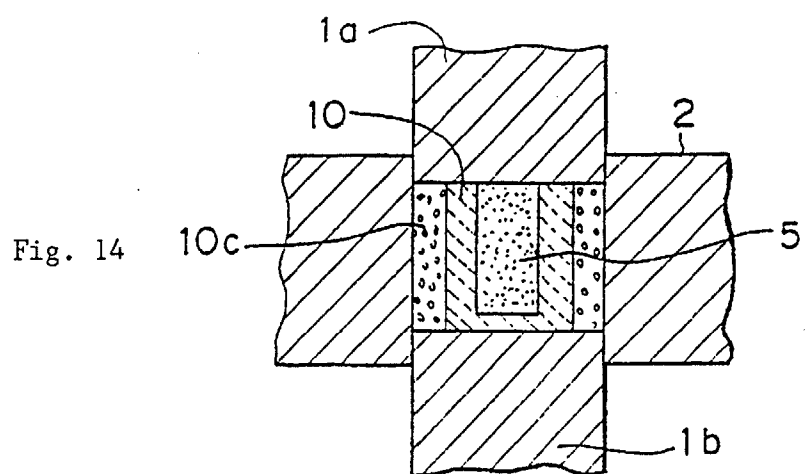
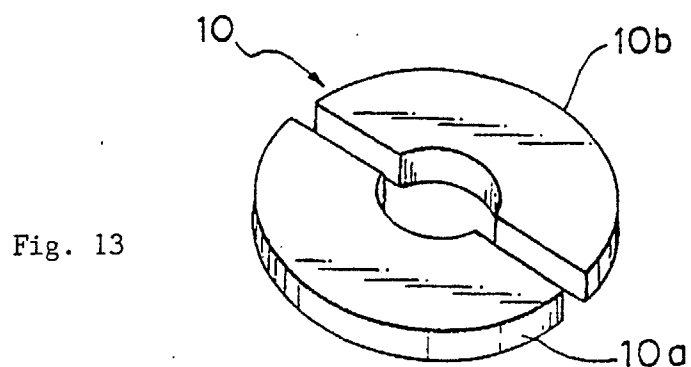


Fig. 16

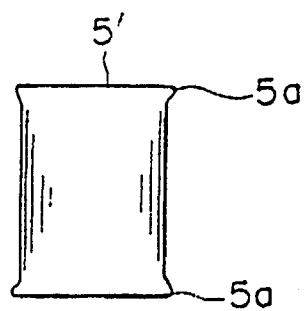


Fig. 17

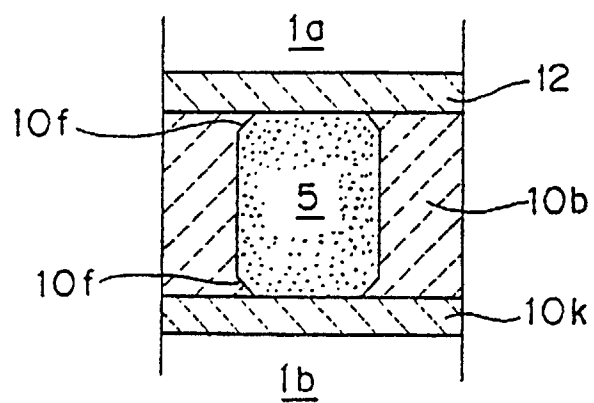


Fig. 18

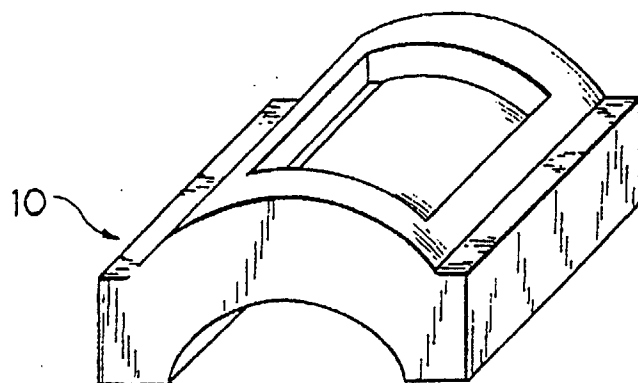


Fig. 19

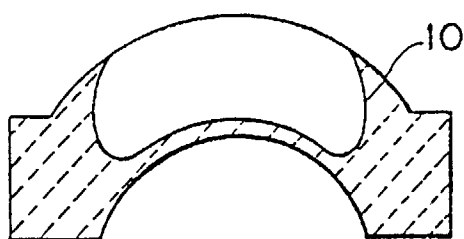


Fig. 20

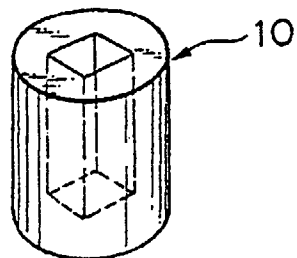


Fig. 21

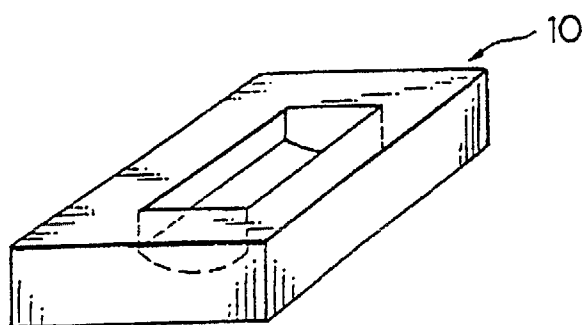


Fig. 22

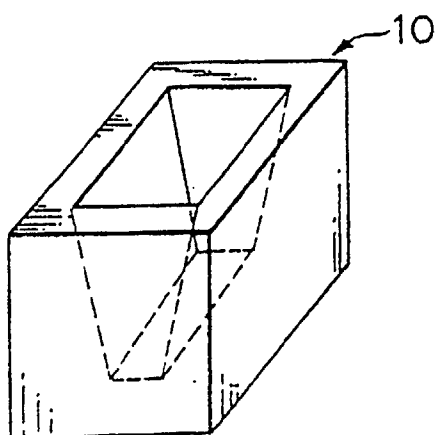


Fig. 23

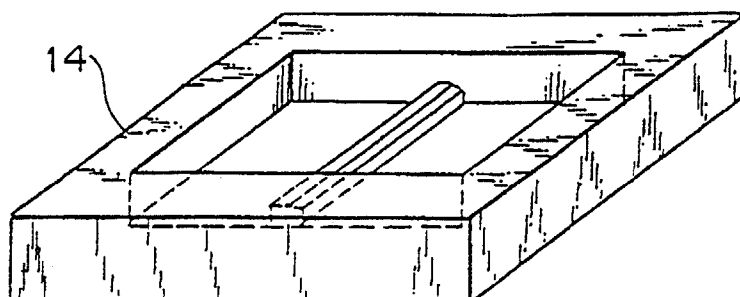


Fig. 24

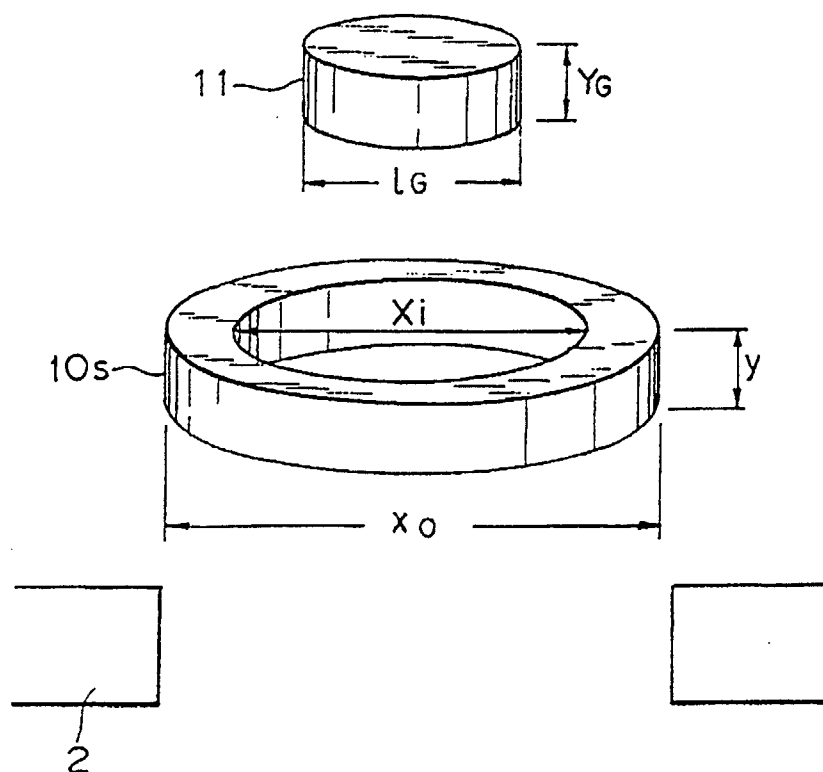


Fig. 25

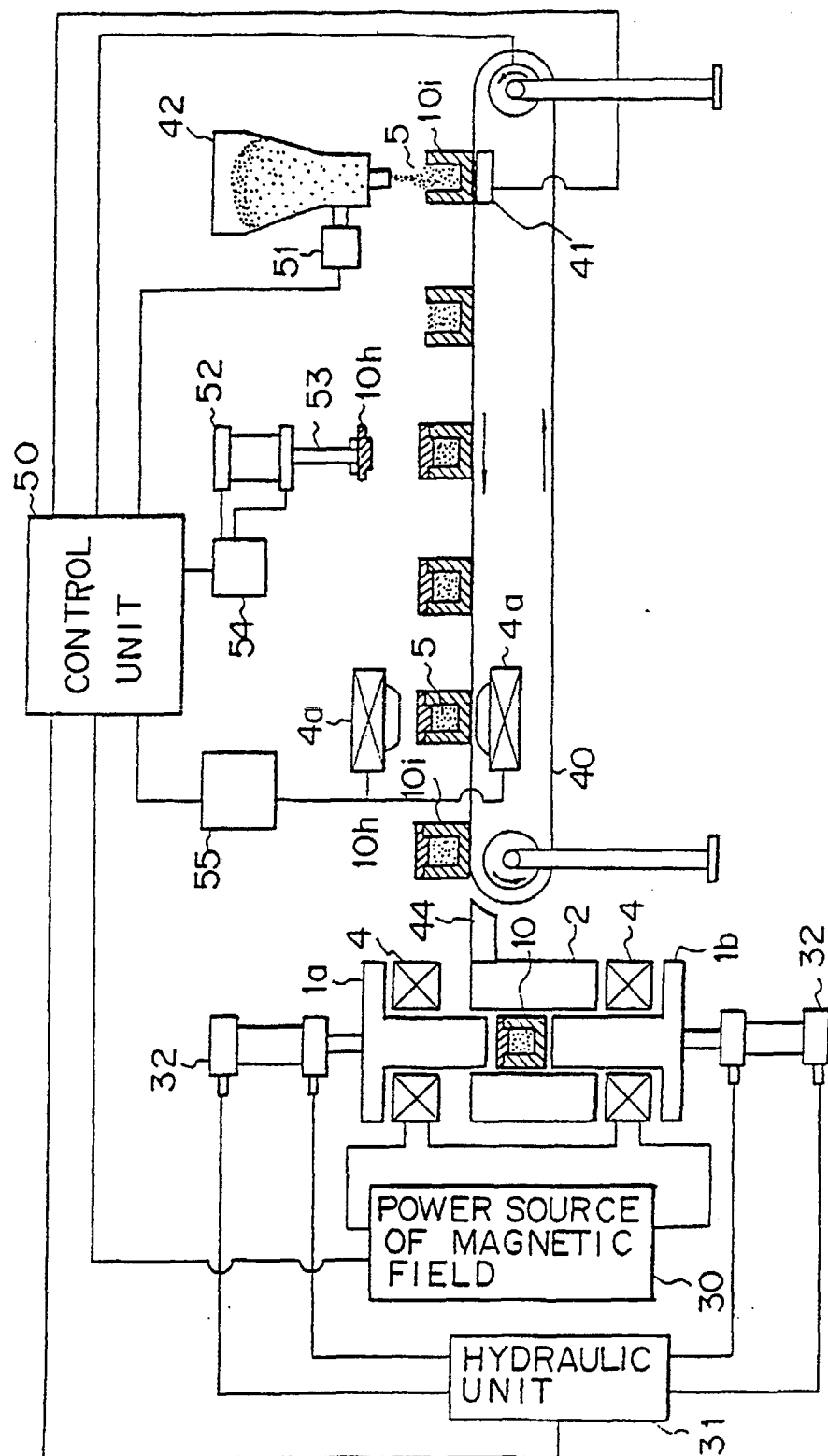


Fig. 26(A)

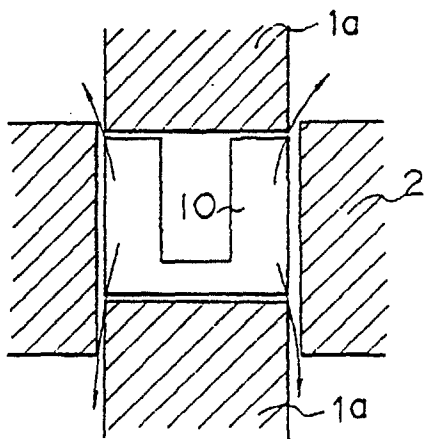


Fig. 26(B)

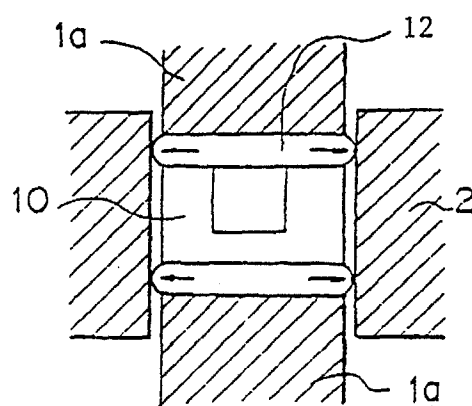


Fig. 26(C)

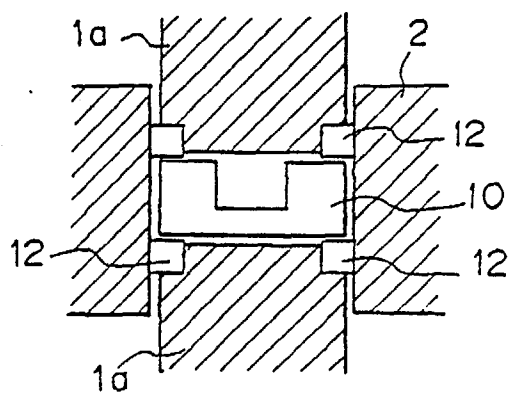


Fig. 26(D)

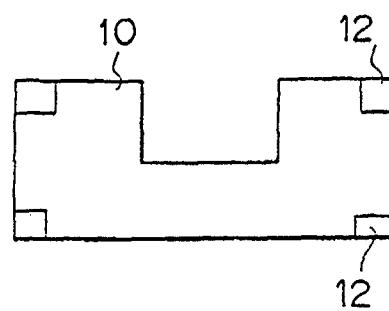


Fig. 27

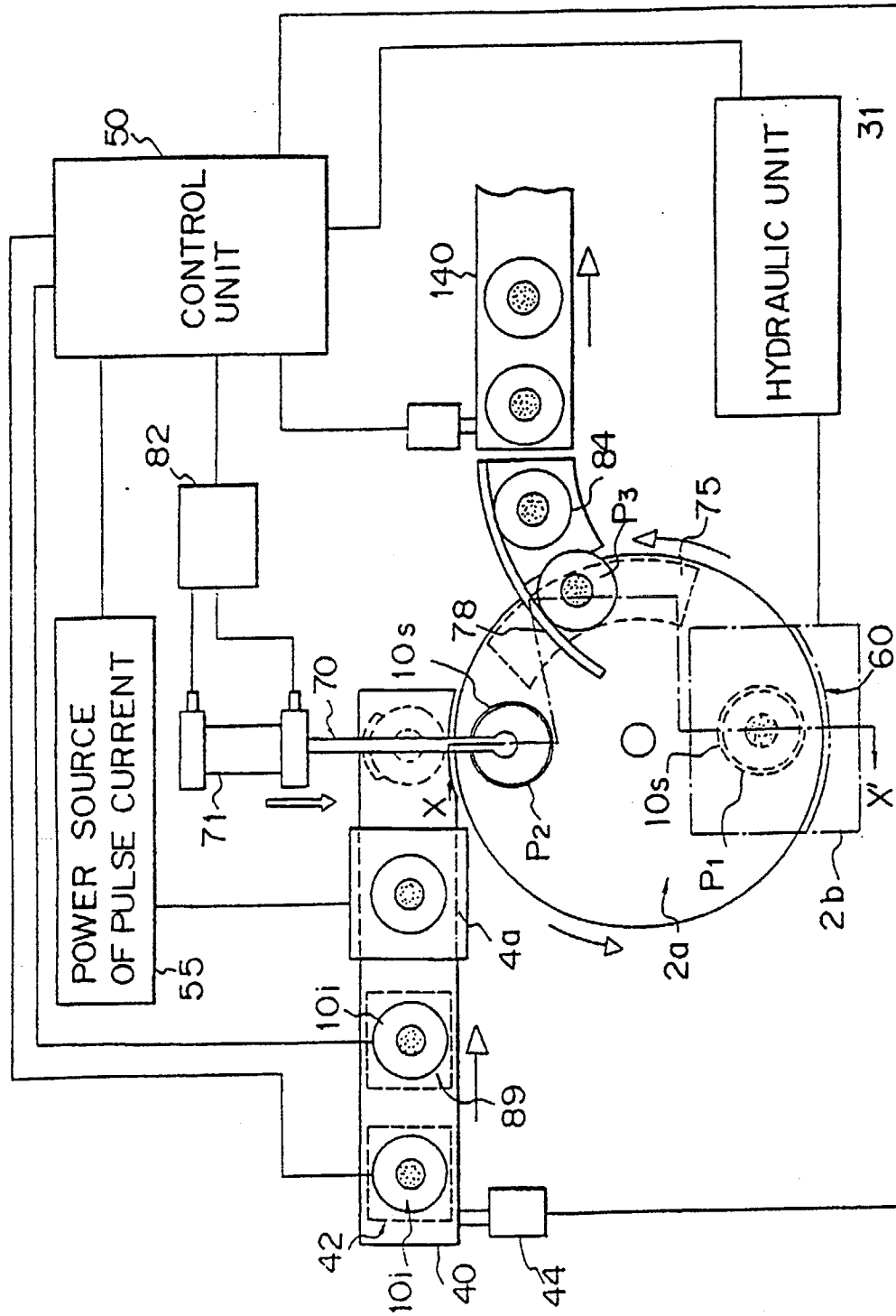
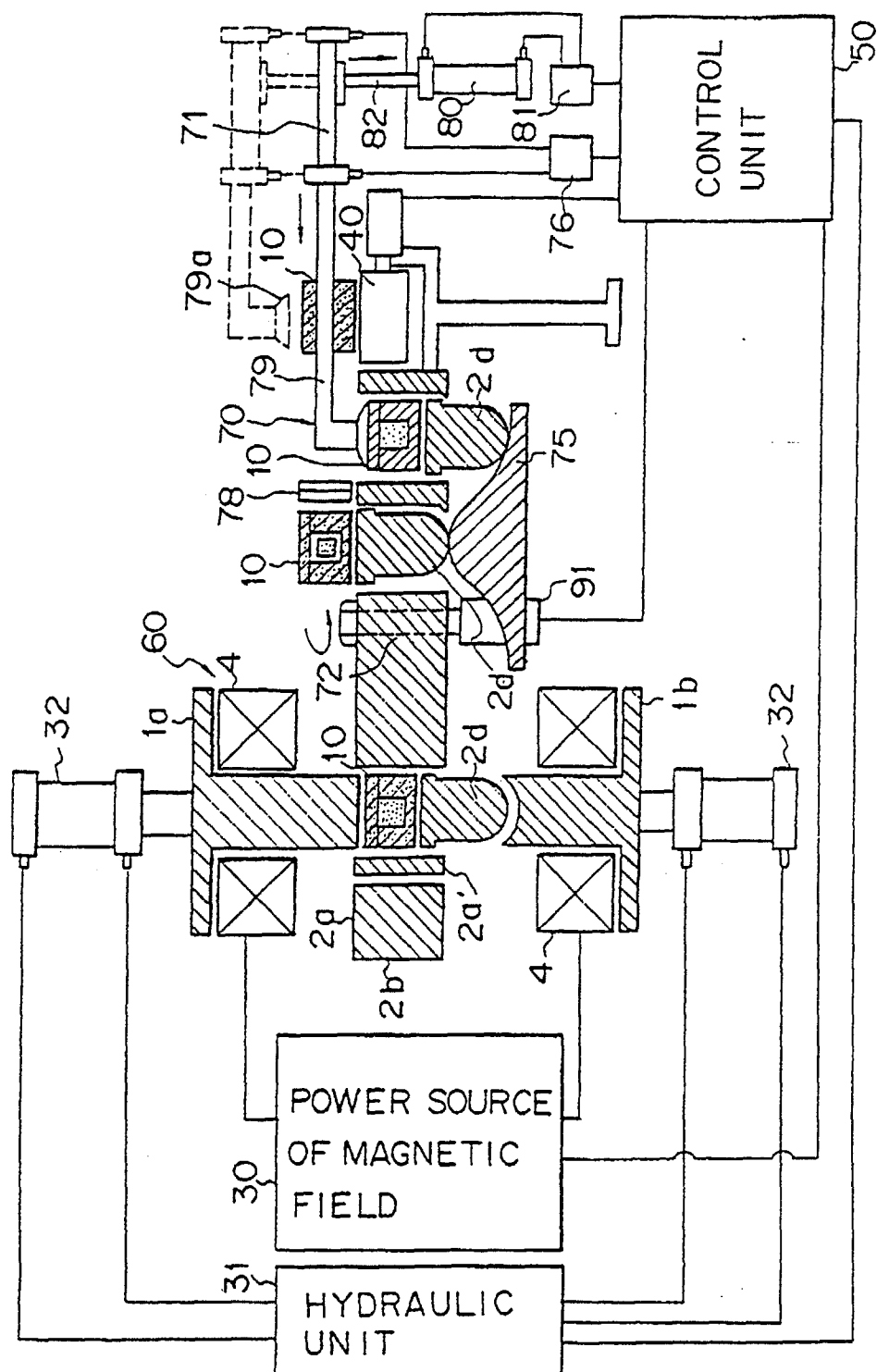


Fig. 28



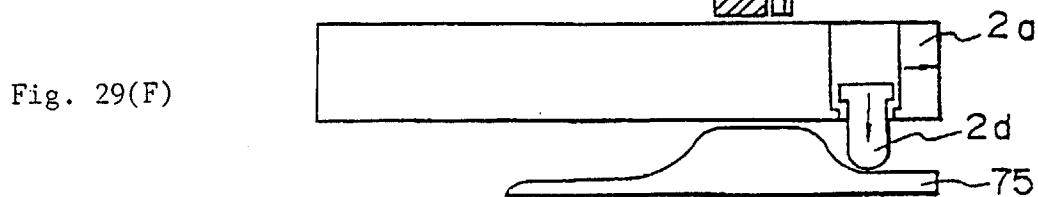
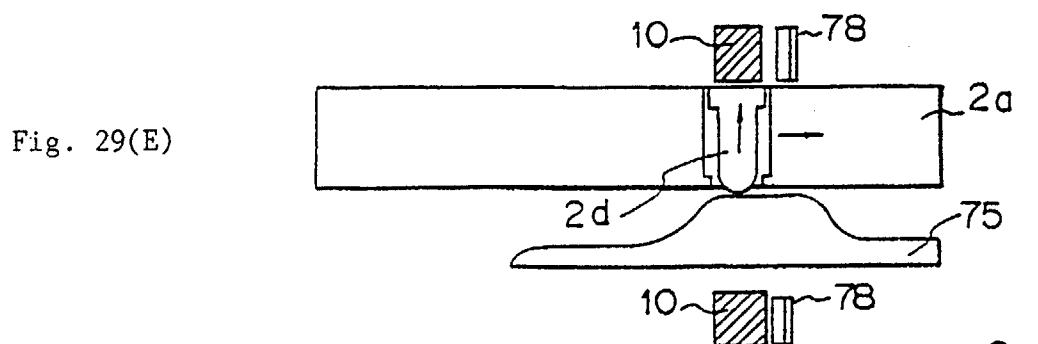
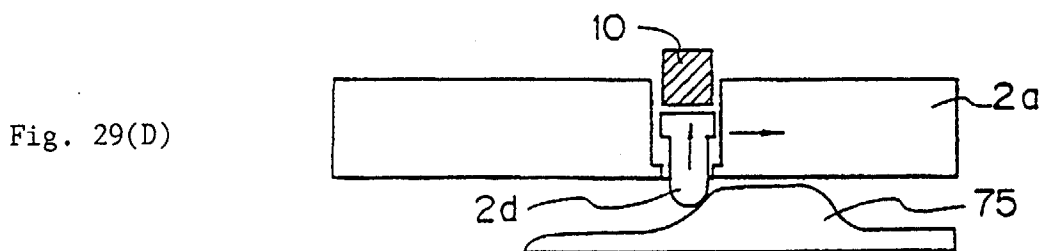
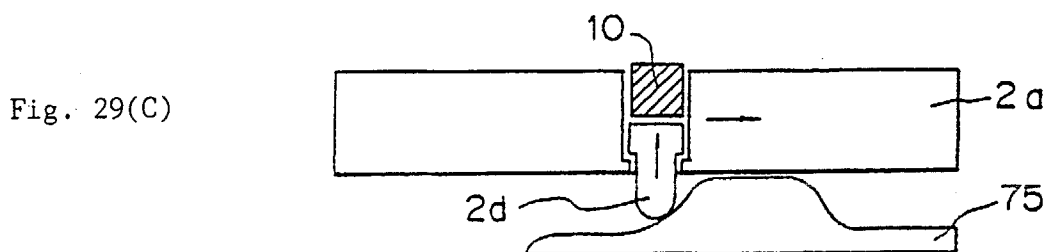
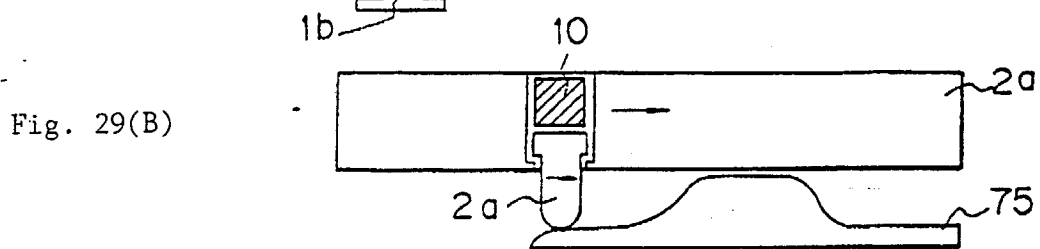
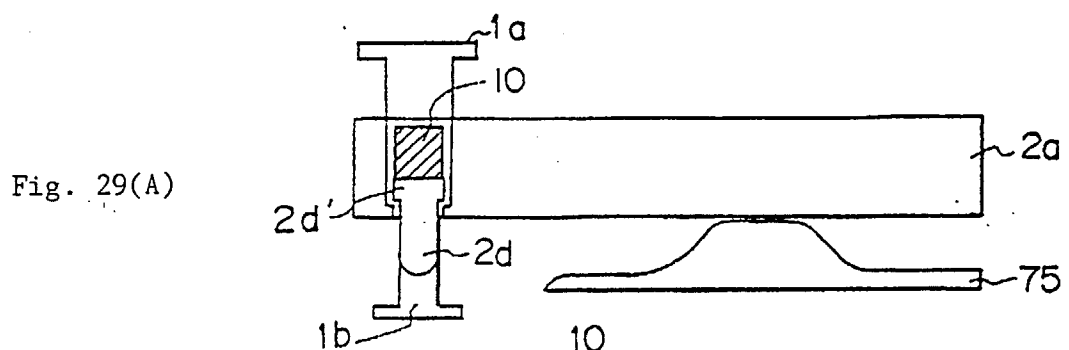


Fig. 30(A)

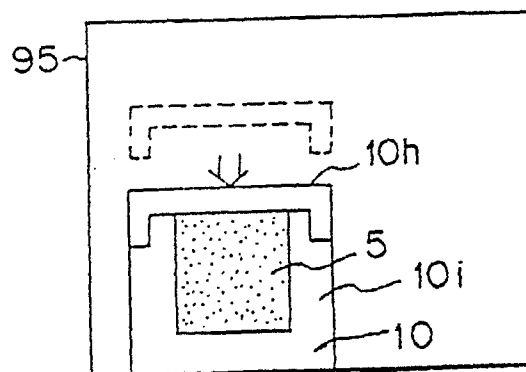


Fig. 30(B)

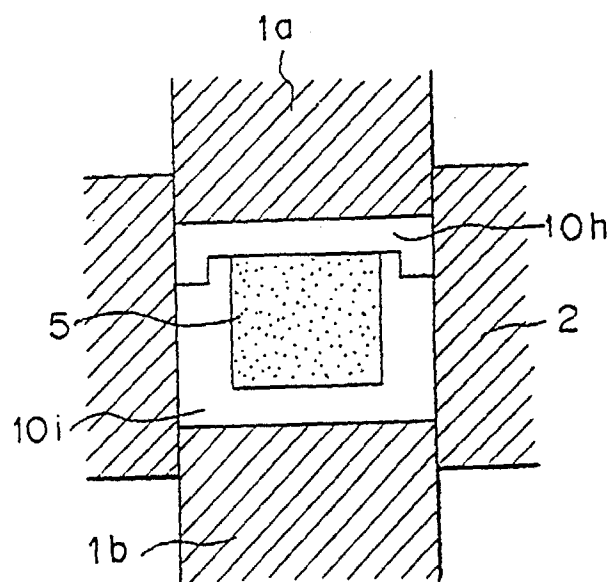
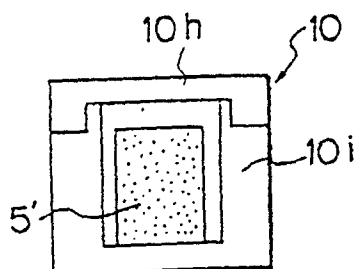


Fig. 30(C)



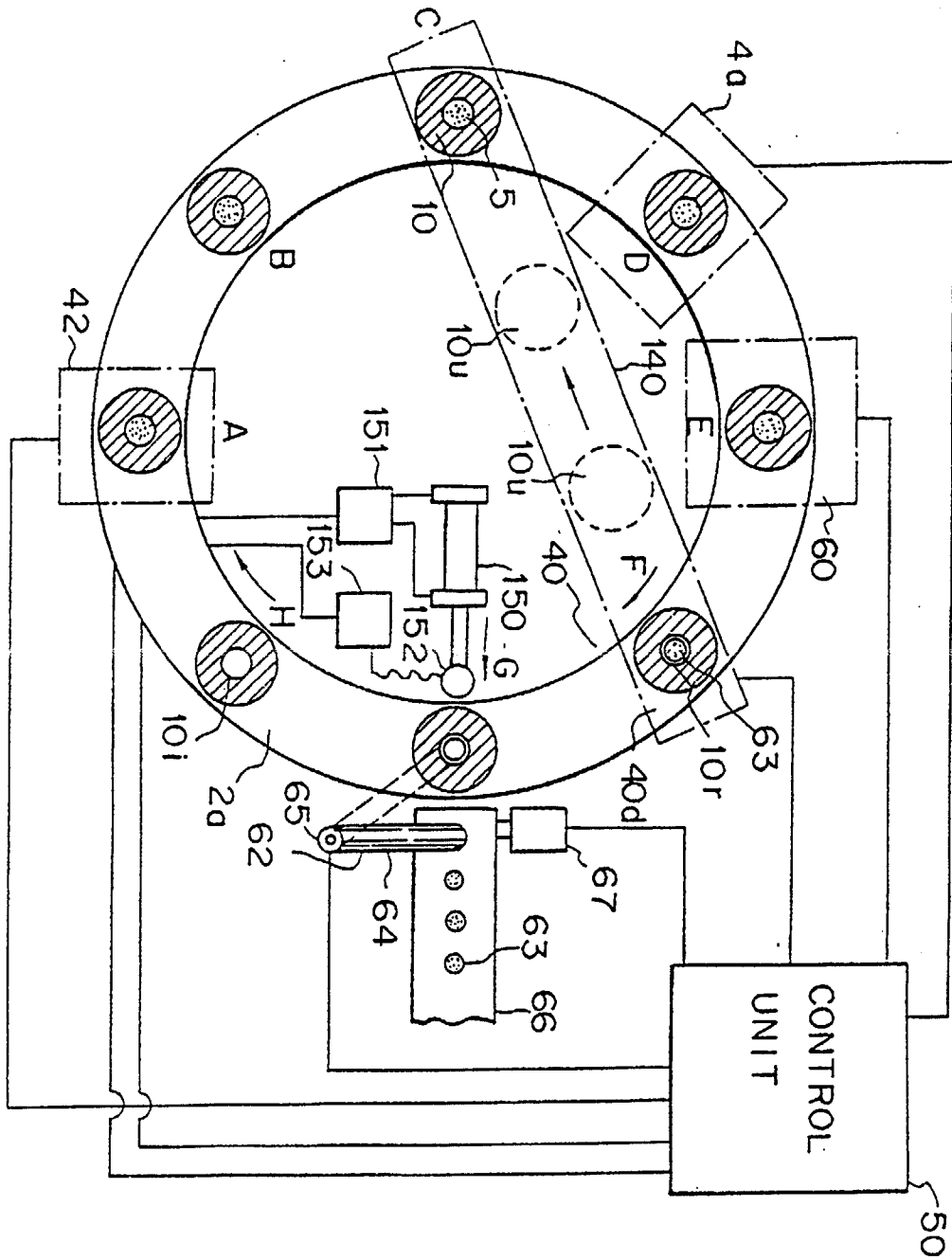


Fig. 31

Fig. 32

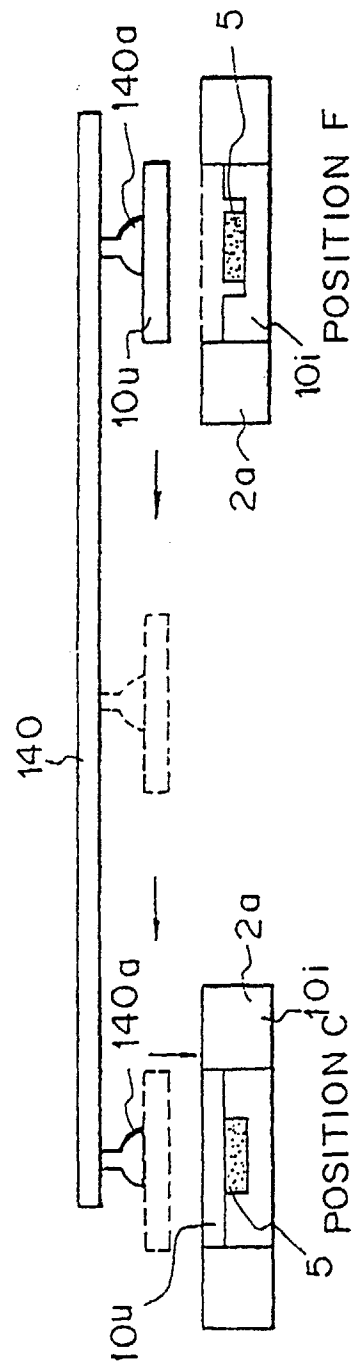


Fig. 33

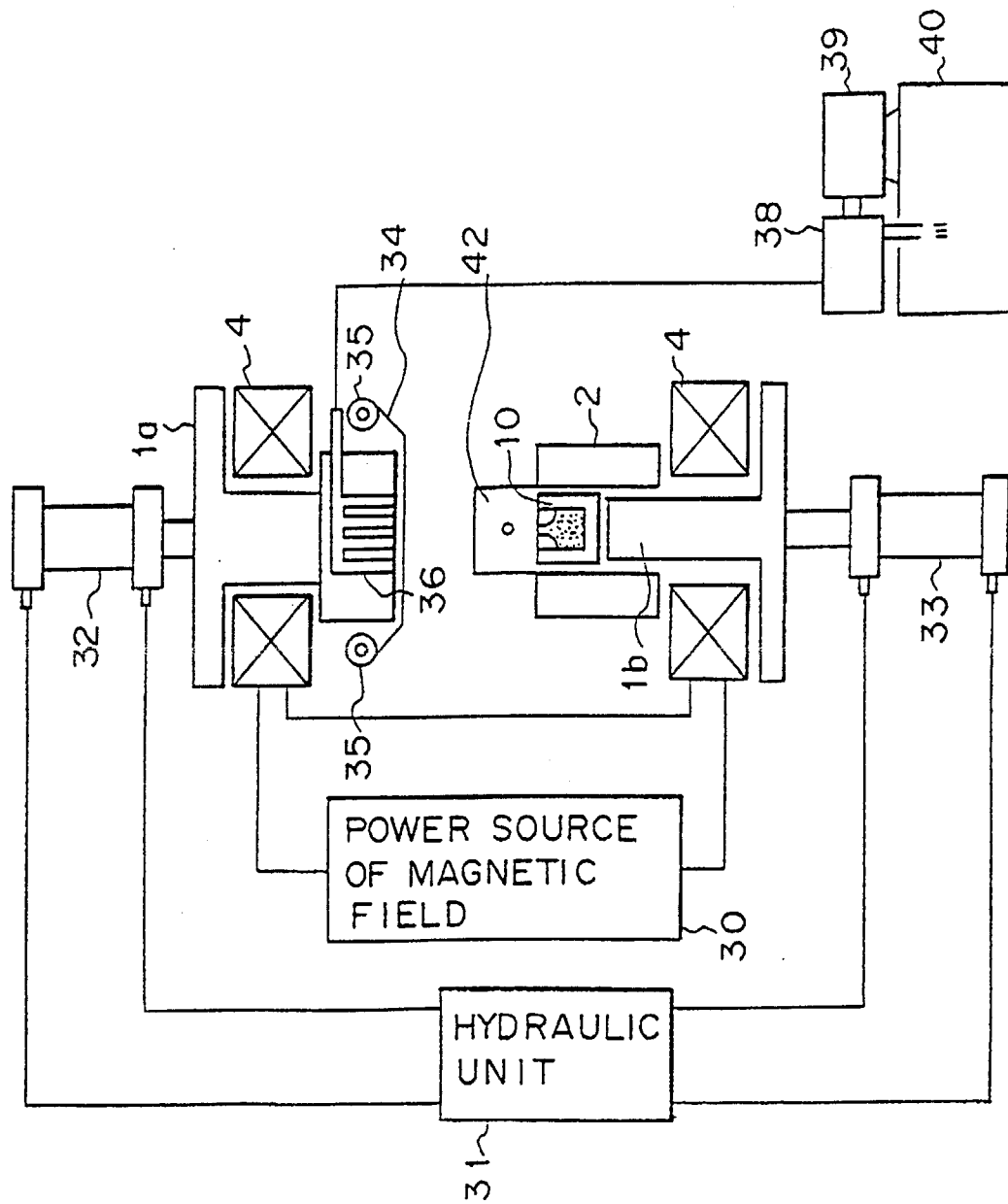


Fig. 34

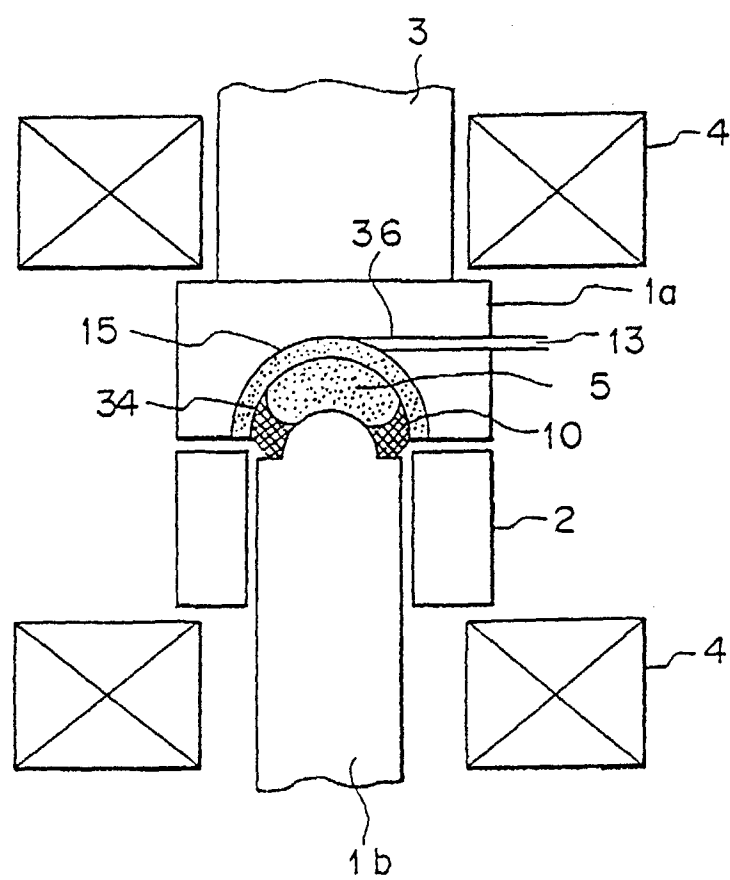


Fig. 35

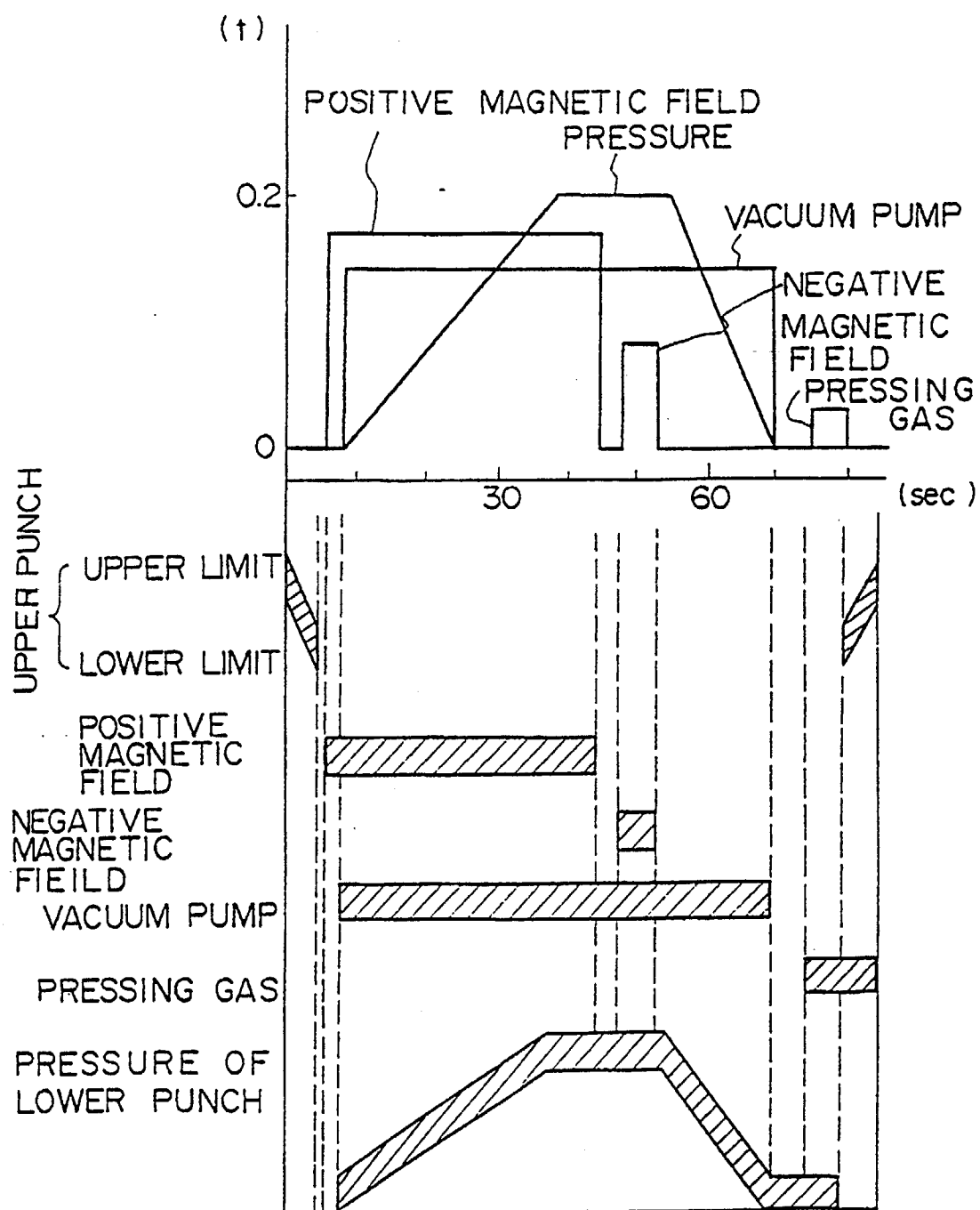


fig. 36

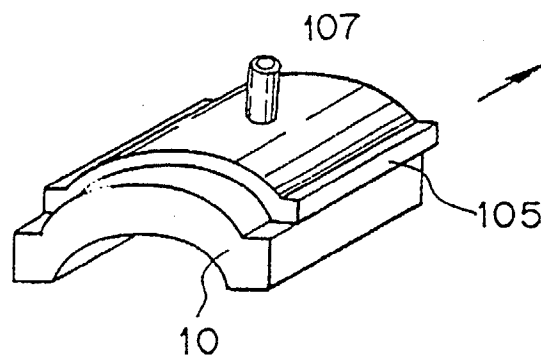


Fig. 37

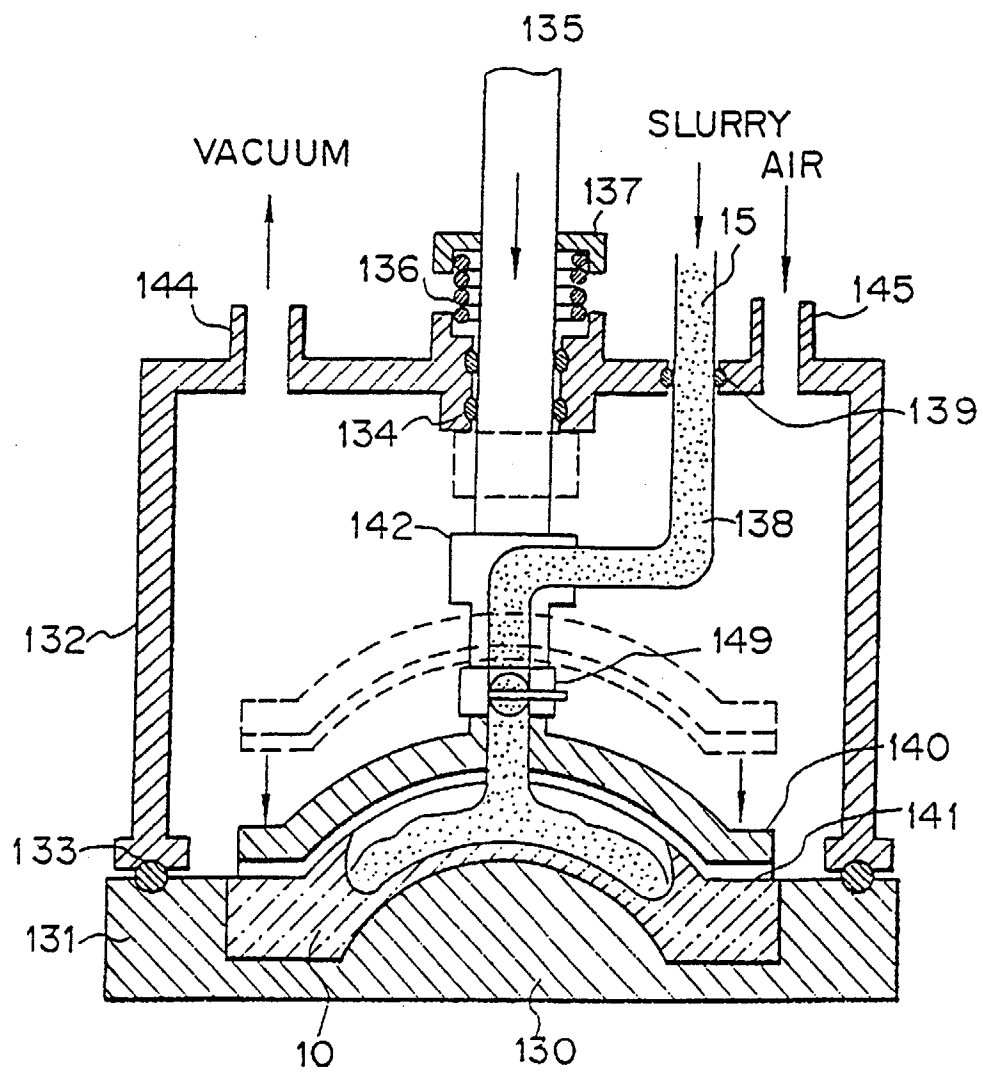


Fig. 38(A)

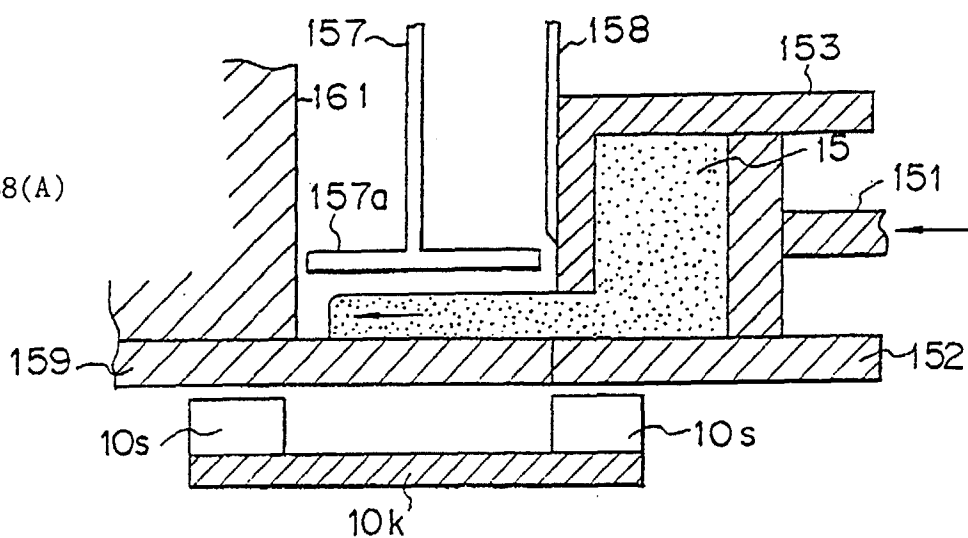


Fig. 38(B)

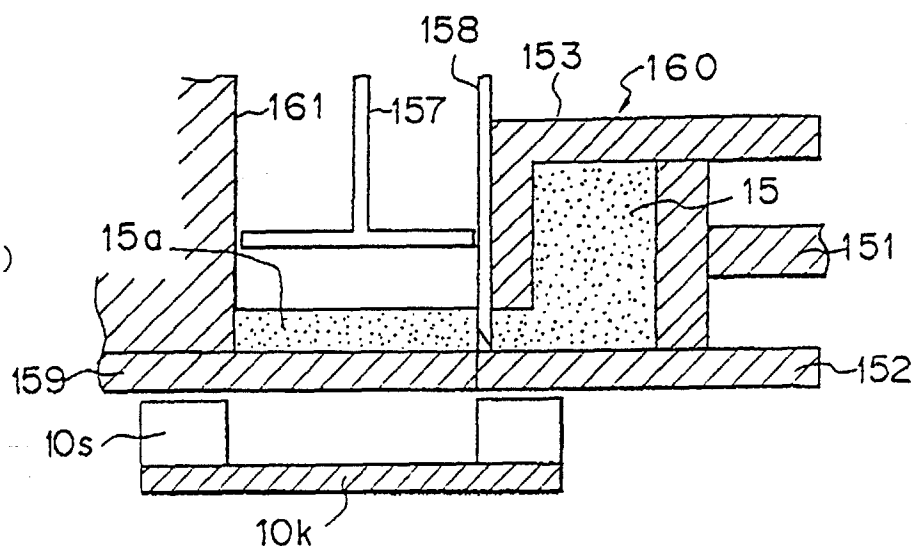
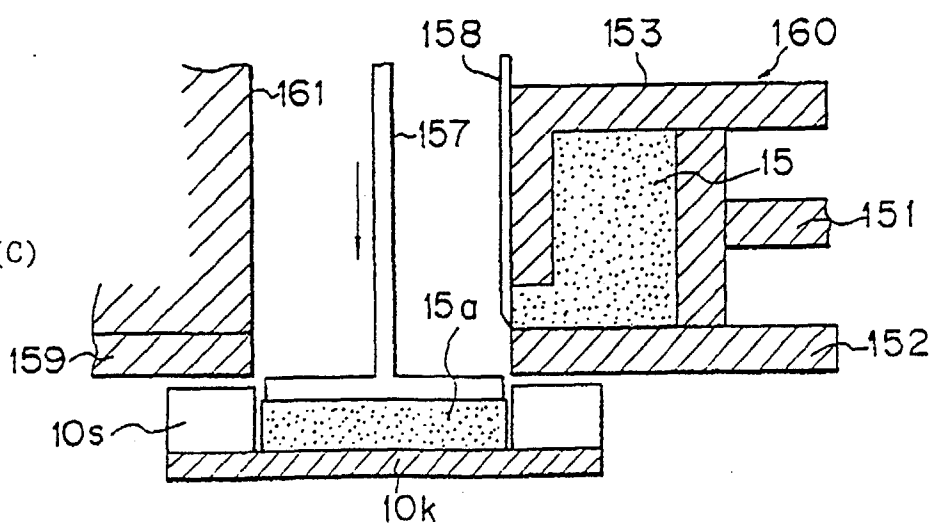


Fig. 38(C)



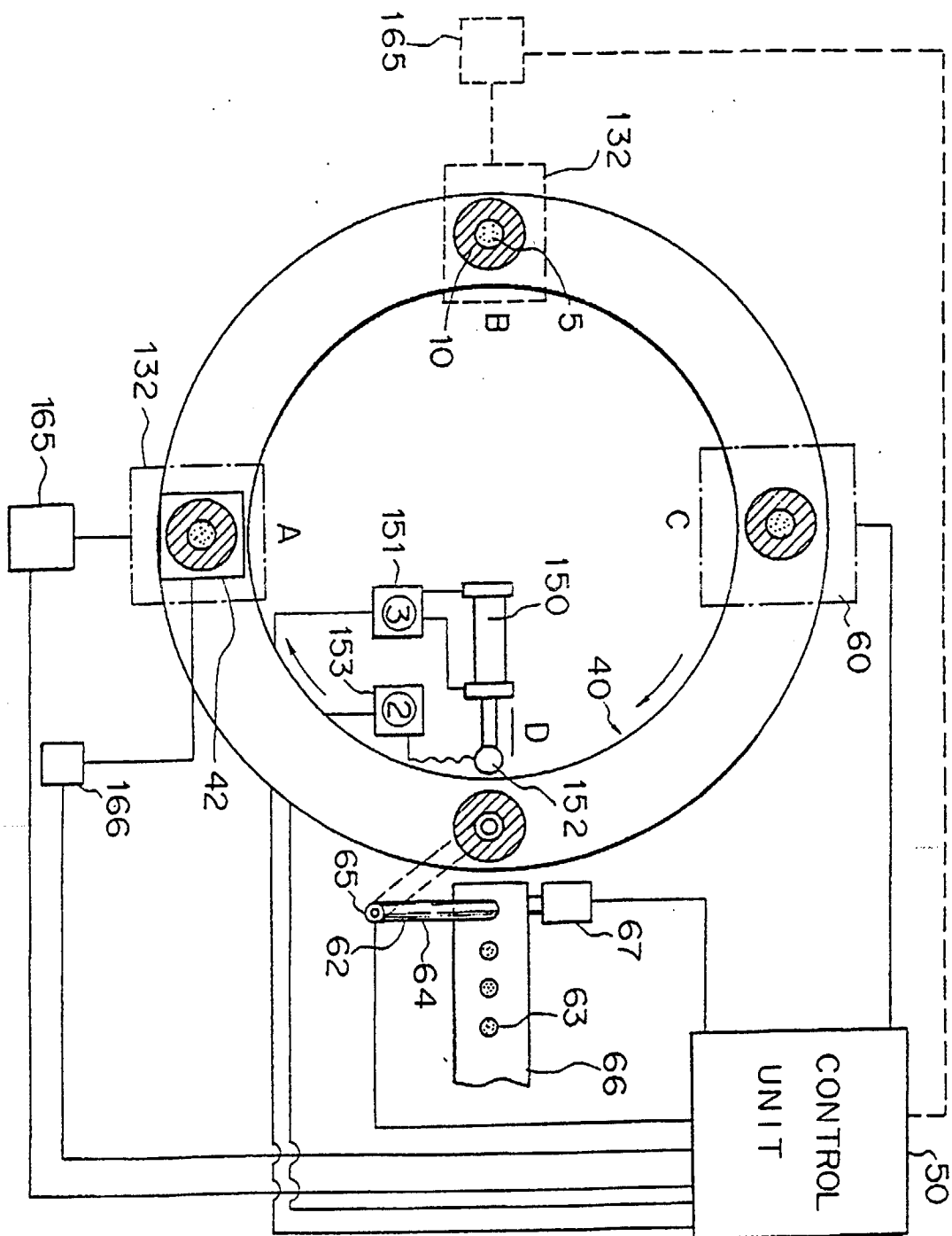


Fig. 39

Fig. 40

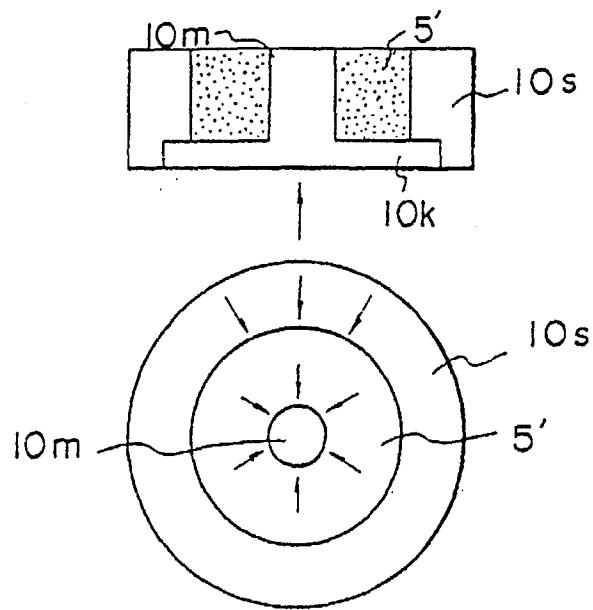


Fig. 41

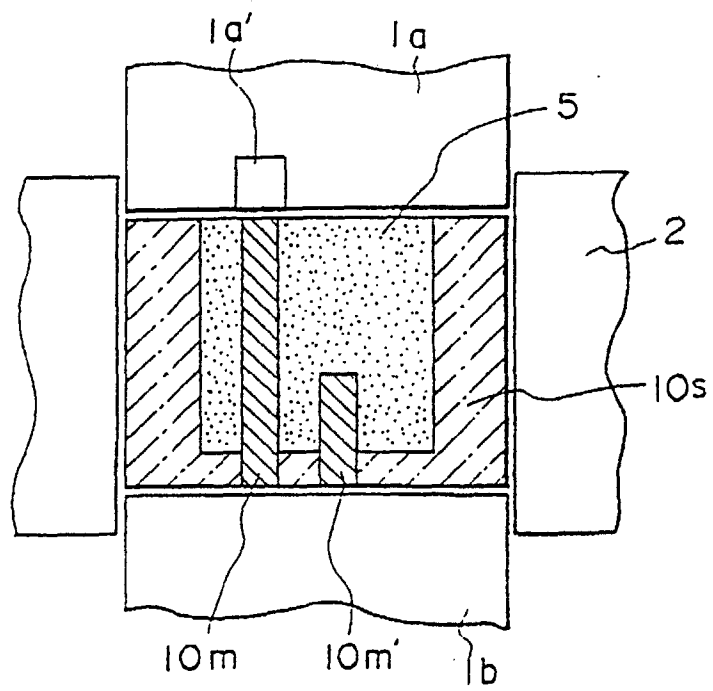


Fig. 42

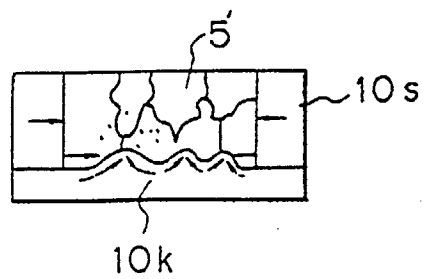
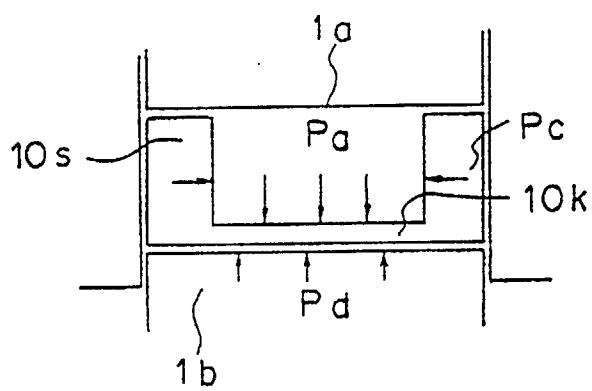


Fig. 43



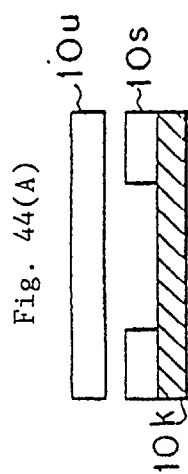


Fig. 44(A)

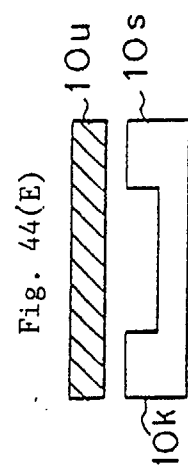


Fig. 44(E)

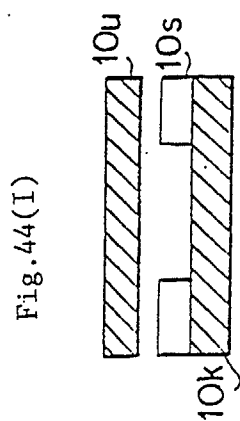


Fig. 44(I)

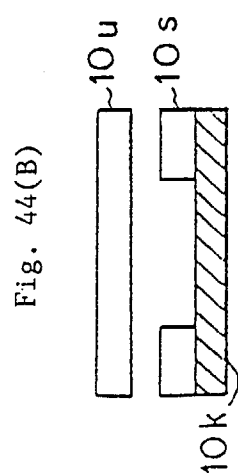


Fig. 44(B)

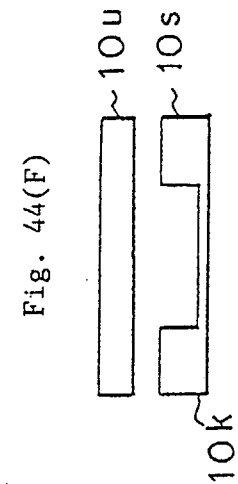


Fig. 44(F)

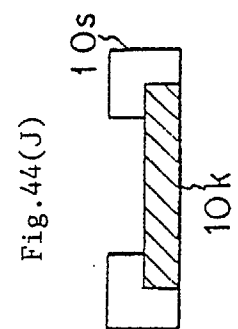


Fig. 44(J)

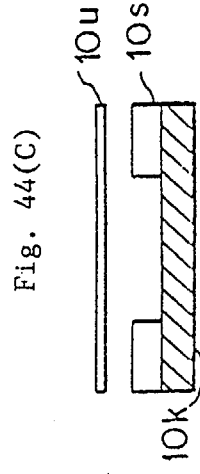


Fig. 44(C)

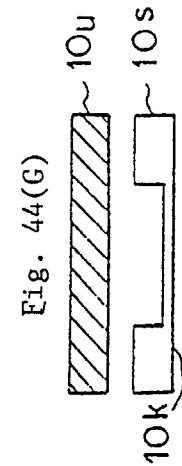


Fig. 44(G)

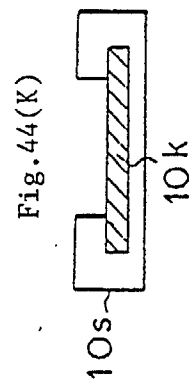


Fig. 44(K)

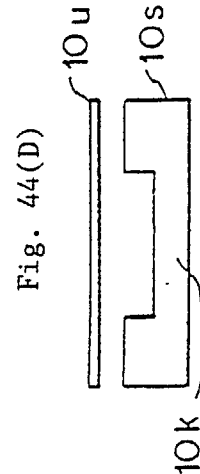


Fig. 44(D)

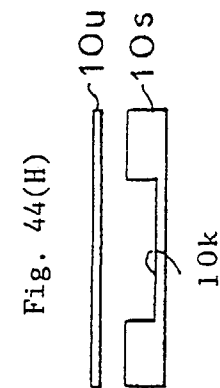


Fig. 44(H)

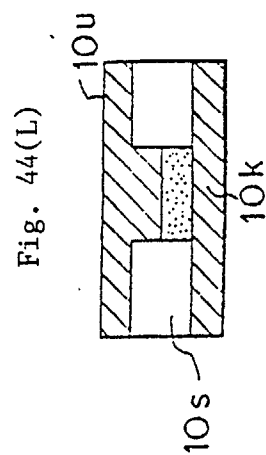


Fig. 44(L)

Fig. 45

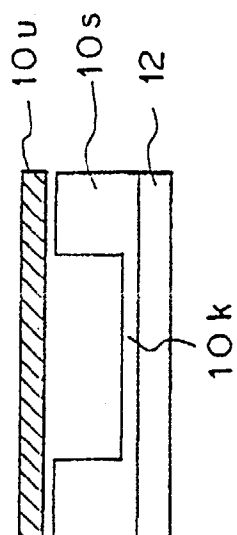


Fig. 46

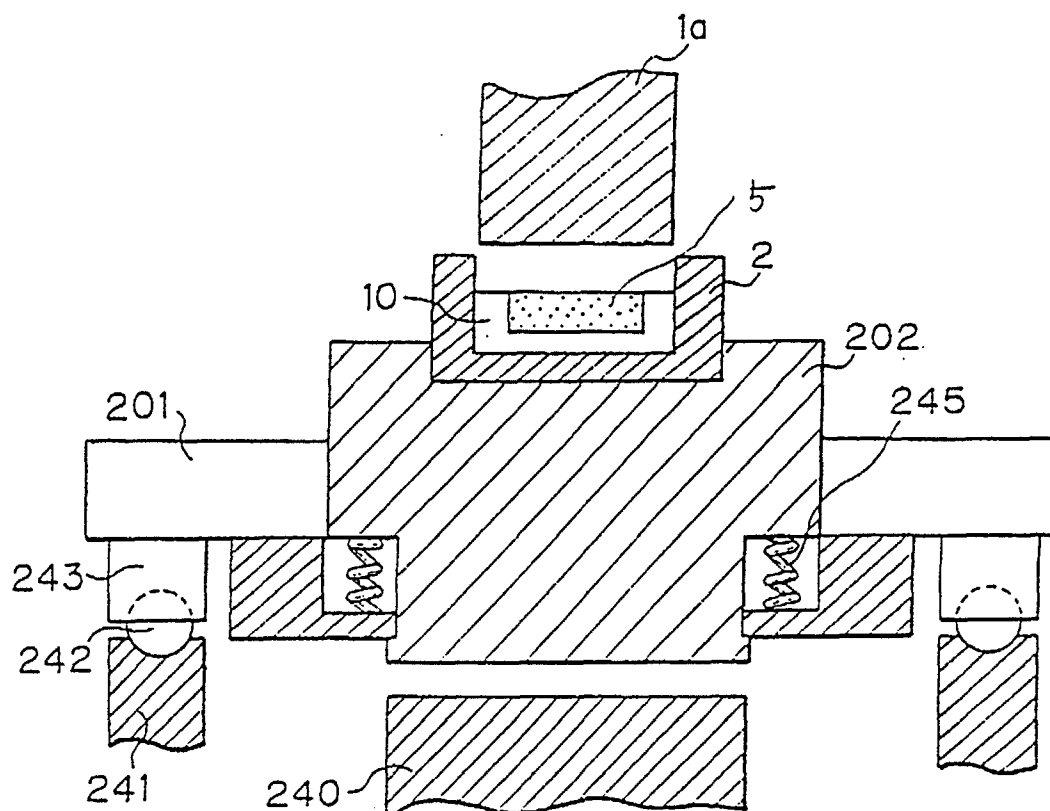


Fig. 47

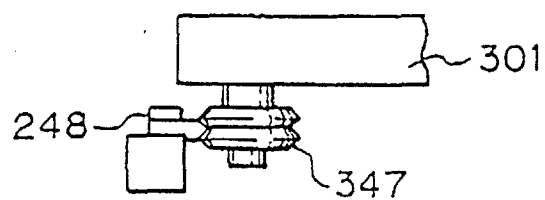


Fig. 48

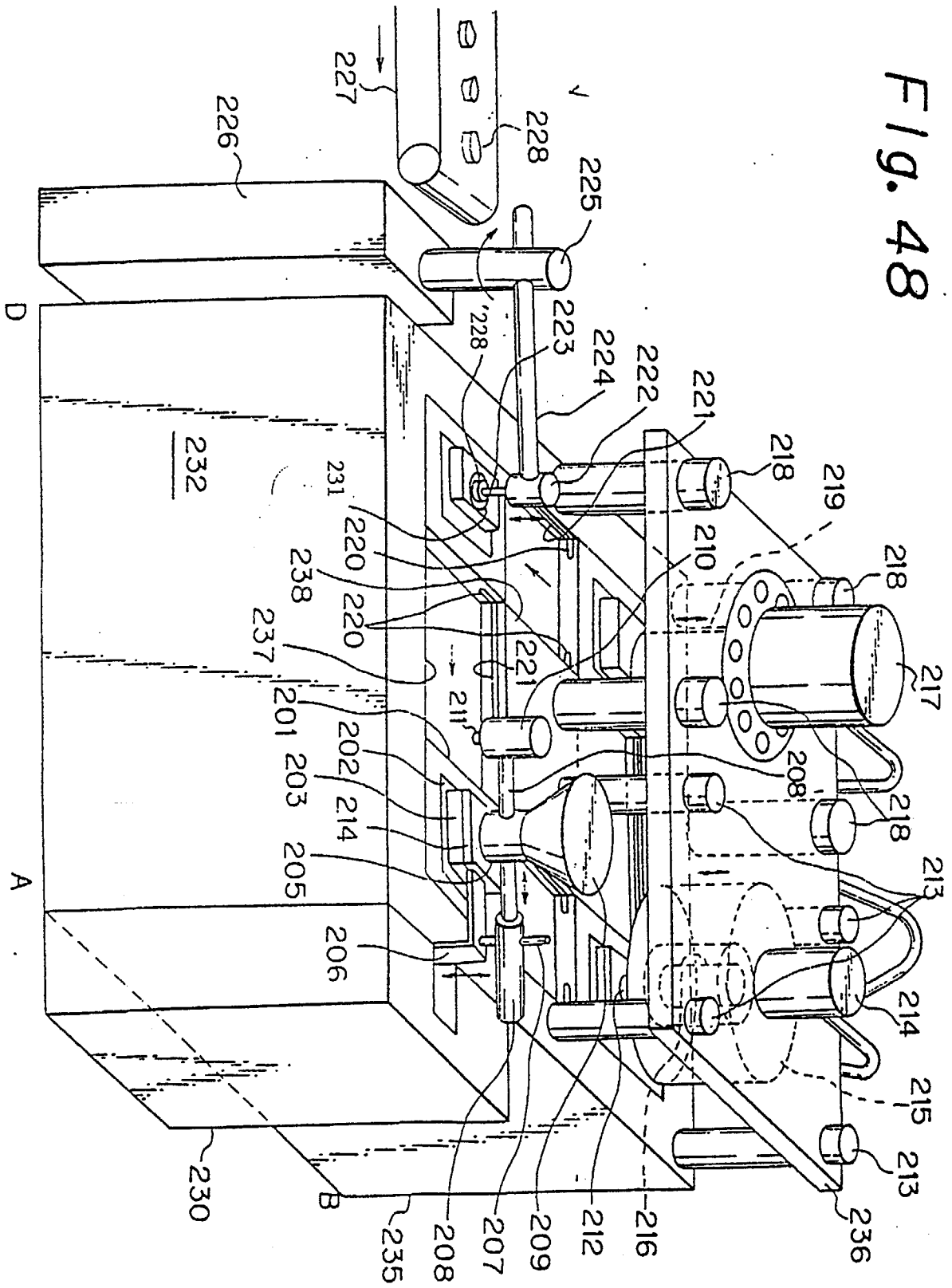


Fig. 49

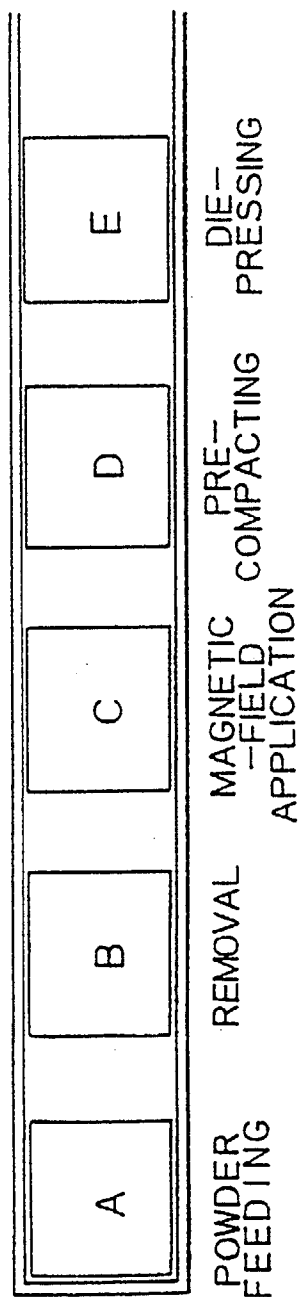


Fig. 50

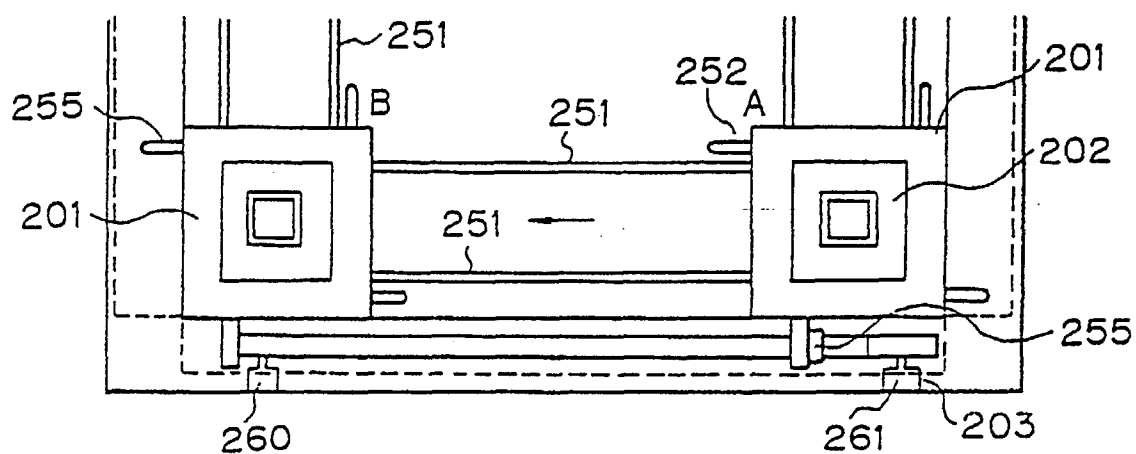


Fig. 51

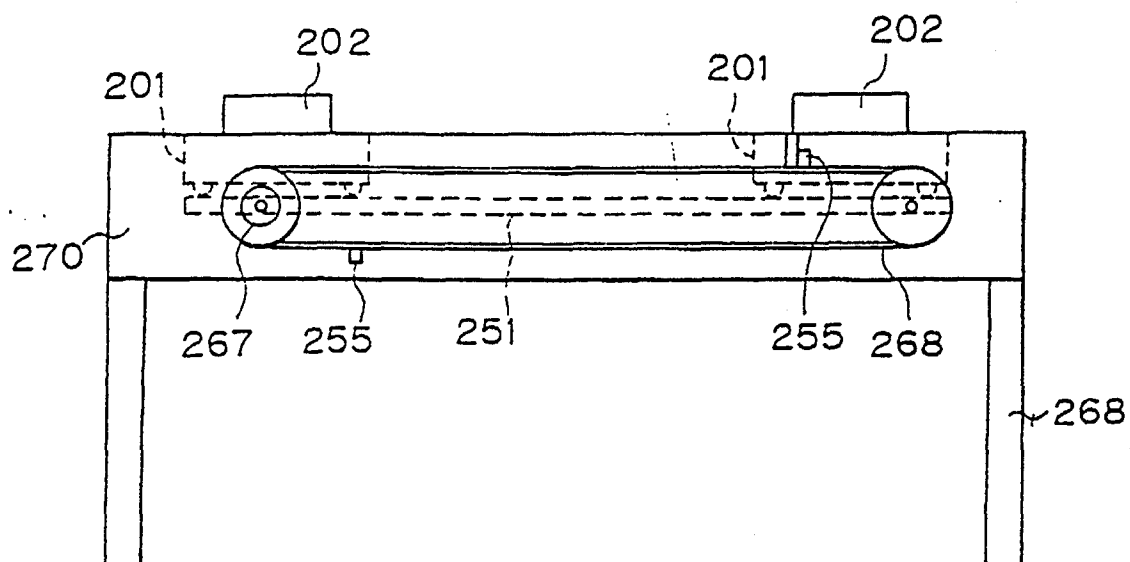


Fig. 52

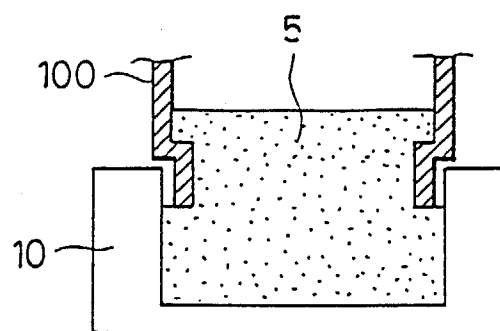


Fig. 53

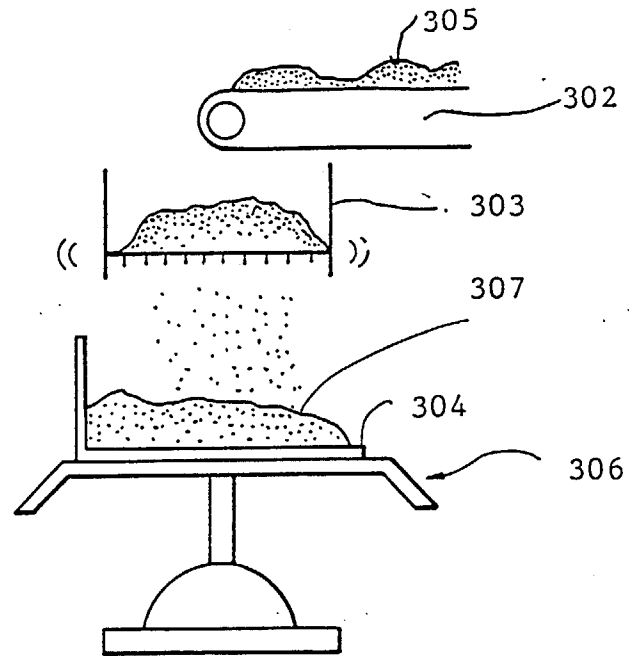


Fig. 54

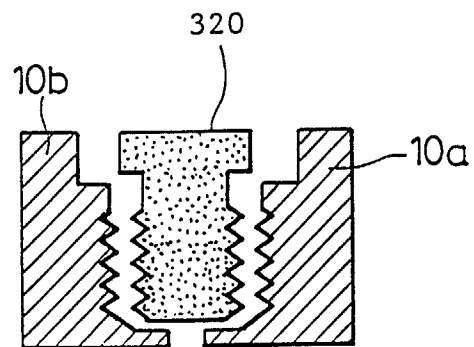


Fig. 55

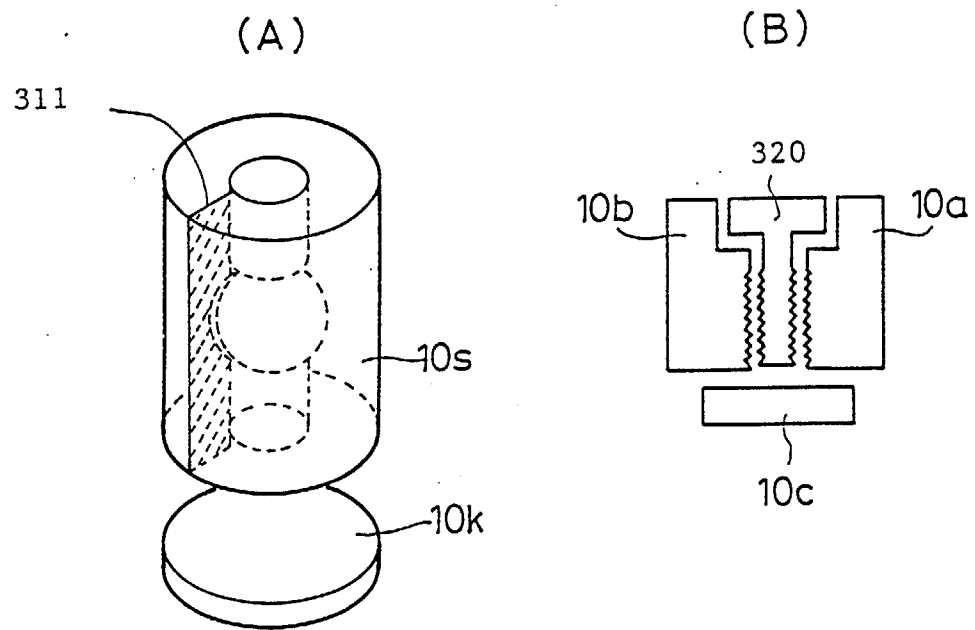


Fig. 56

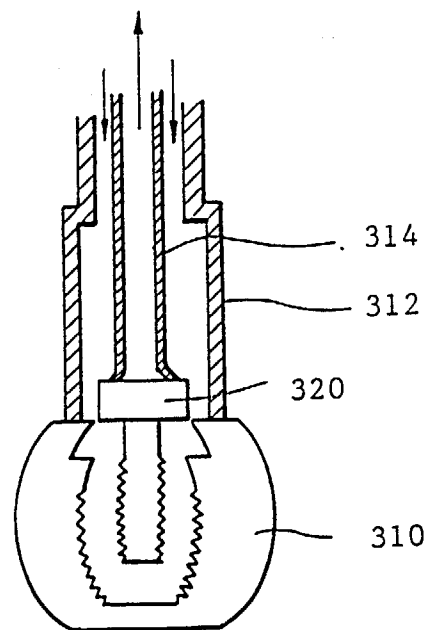


Fig. 57

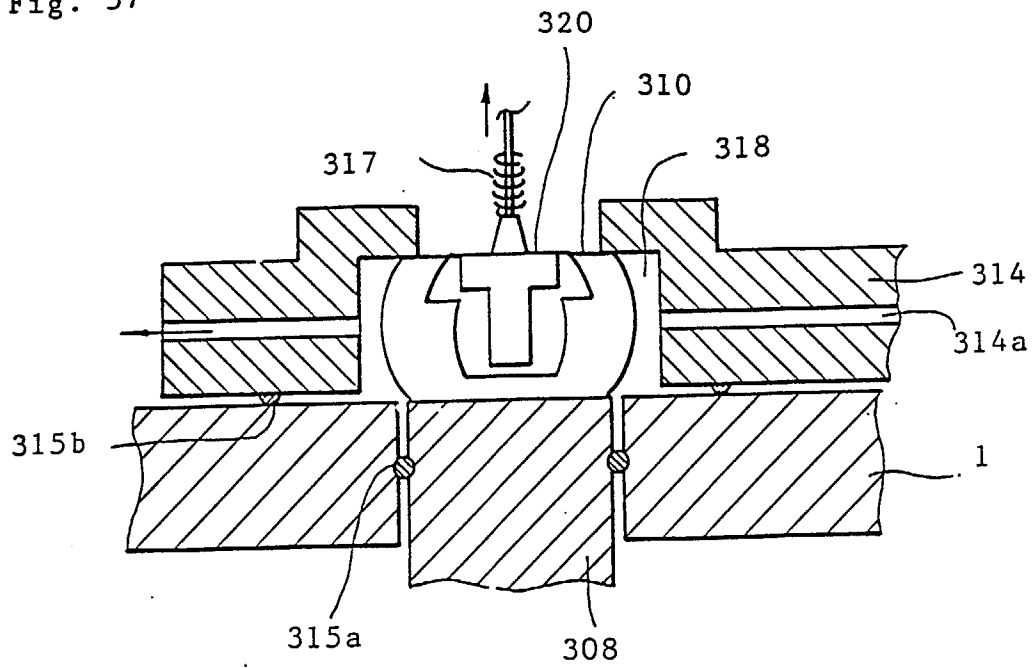


Fig. 58

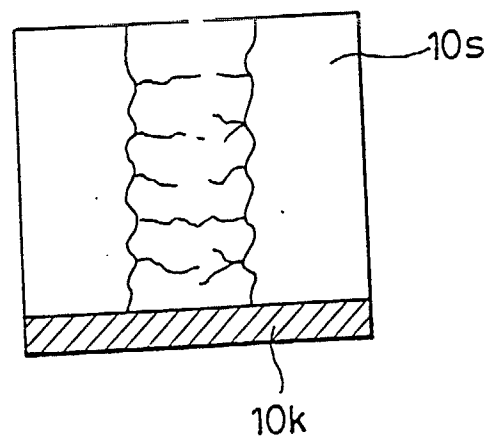


Fig. 59

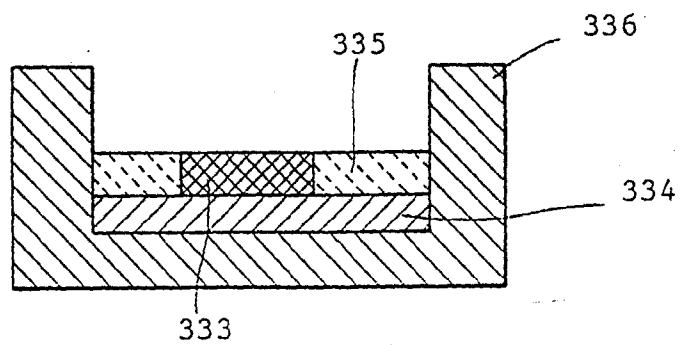


Fig. 60

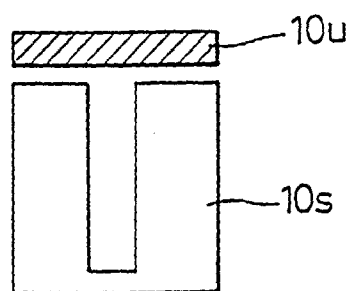


Fig. 61

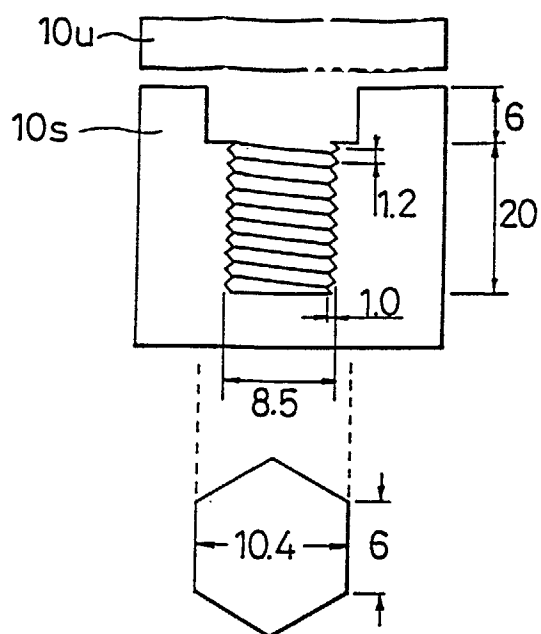


Fig. 62

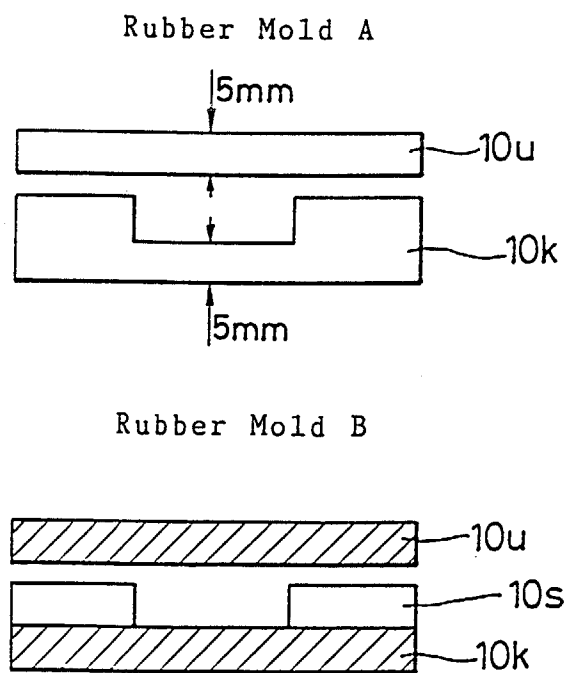


Fig. 63

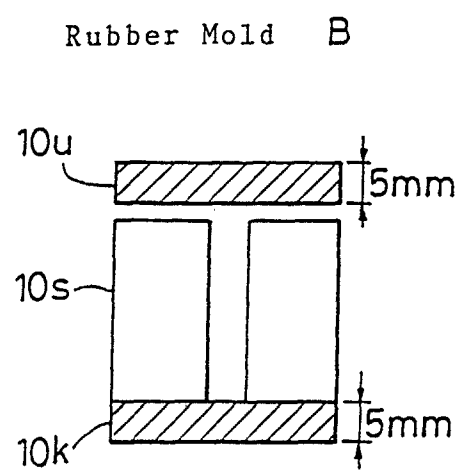
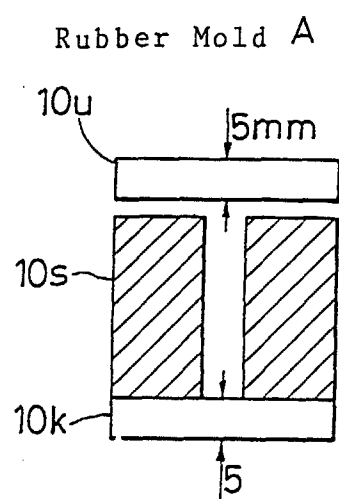


Fig. 64 (A)

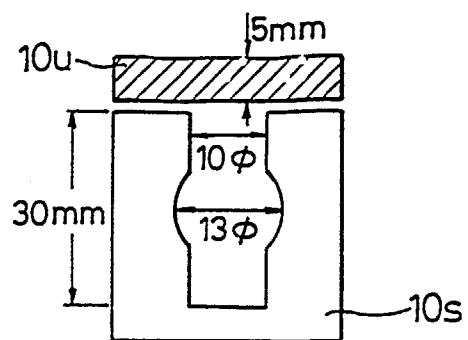


Fig. 64 (B)

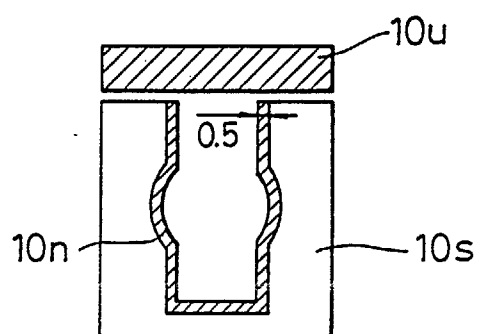


Fig. 64 (C)

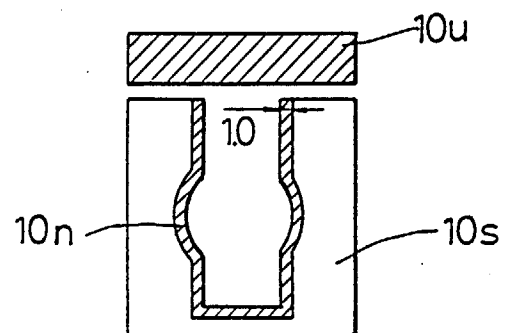


Fig. 65 (A)

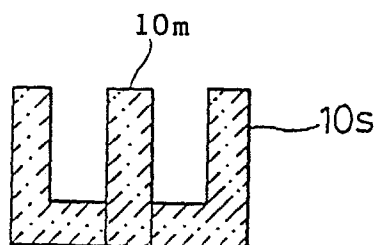


Fig. 65 (B)

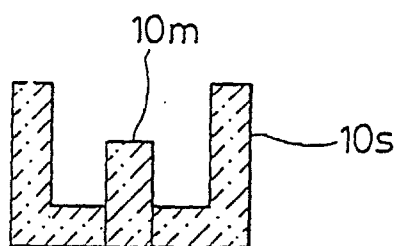


Fig. 65 (C)

